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IRRIGATED CROP ROTATIONS IN WESTERN SOUTH DAKOTA

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INTRODUCTION

The Belle Fourche reclamation project is located in western South Dakota about 25 miles north and slightly east of the city of Deadwood on the edge of the Black Hills region and embraces about 75,000 acres of irrigable land with an altitude above sea level of approximately 2,900 feet. The project draws its water supply from the Belle Fourche and Red Water Rivers, which are diverted into a storage reservoir. The total area under irrigation in western South Dakota, including the Red Water, Spearfish, and Rapid City Valleys, is about 125,000 acres. The topography of the area within the project is gently rolling. Owing to the topography, a substantial acreage of nonirrigable land is included within the confines of the district, and many project farmers have from a few to several hundred acres of such land included in their holdings.

The soils of the project vary from a sandy loam to a heavy fine clay. There is a comparatively small area along the Belle Fourche River, most of which is on the south side in the Vale section, where the lighter soil occurs. The soil on the major part of the irrigable land is a heavy clay known locally as "gumbo" and designated technically in the United States Bureau of Chemistry and Soils survey of the region as Pierre clay. This soil has resulted from the weathering of the original shale, which is now covered by a soil blanket in some places 5 feet or more in thickness. In many places the soil cover is much thinner, particularly on hillsides. Generally there is a well-defined bed of cracked and fissured shale lying between the soil blanket above and the compact shale below. Water moves

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almost as readily through this zone of fissured shale as it would through a zone of coarse sand or gravel.

The native vegetation consisted mainly of a buffalo grass on the better soil types and a rather scattered growth of western wheatgrass on the poorer lands. The soil on the Belle Fourche Field Station of the Bureau of Plant Industry, United States Department of Agriculture, consists largely of a heavy gumbo, which is considered less desirable than that generally under cultivation on the project. This is particularly true of field A, where the irrigated rotation experiments herein reported are located. When climatic conditions are favorable and the land is properly cultivated, good yields are usually harvested; but owing to the refractory nature of the soil special care must be taken when it is cultivated if satisfactory results are to be expected. The addition of humus has been found to improve materially the structure of such soils.

Cultural operations can be performed only when the moisture content of the soil is well below the field capacity. It is impracticable to plow, cultivate, or plant when the soil is too wet. Consequently, farmers often find it impracticable to perform these operations at the most suitable or convenient season, and serious delays may occur during periods when frequent showers are experienced.

Climatological records have been kept at the Belle Fourche Field Station for the 22-year period 1908 to 1929. The average annual precipitation for this period has been 16.53 inches, the average for the growing season, from April 1 to October 1, being 12.46 inches. If showers are not too frequent, they are of material aid in getting the crops started in the spring. The evaporation from a free-water surface from April 1 to October 1 for the 22 years has averaged 35.96 inches. The records during the 22 years indicate an average frost-free period in summer of 137 days.

The more important crops that have been grown on the project are alfalfa, cereals (including barley, wheat, and oats), sugar beets, corn, potatoes, and miscellaneous hay and pasture crops. Those grown chiefly for sale are sugar beets and the cereals, and of these sugar beets in recent years have become increasingly important. The forage crops, including alfalfa, are largely consumed locally by livestock produced on the farms or brought in from adjoining ranges to be fattened for market. In 1929 the Bureau of Reclamation crop census indicated that approximately 35 per cent of the total cropped acreage of the project was in alfalfa. This crop serves a dual purpose; it is grown both for hay and for soil-improvement purposes. Because of the distance from large consuming centers, farmers have found it necessary to give serious consideration to methods of crop utilization, particularly when alfalfa is used in the planting program for its beneficial effects on yields of later crops.

In 1912 a series of rotation experiments was begun at the Belle Fourche Field Station, which is located on the Belle Fourche reclamation project. The station is situated 28 miles east of the town of Bellefourche and 2½ miles northwest of the town of Newell. It was first established in 1907, but irrigation water was not available until the crop season of 1912. Part of field A, where these experiments are being conducted, was broken from native sod in the summer of 1908 and cropped to cereals in 1909 and 1910. The remainder of the field was broken in 1911, and the whole field was fallow during that

year. In the fall of 1911 the field was laid out in three series, running north and south, 264 feet wide, and separated by roadways 40 feet wide, with an irrigation ditch near the center of each roadway. The plots are separated by 5-foot alleys except that a 20-foot crossroad occurs between plots 36 and 37 and a vacant plot on each side of the crossroad between plots 18 and 19. The series are numbered I to III east to west and the plots 1 to 52 south to north.

OBJECTIVES OF THE ROTATIONS

The rotations conducted at the Belle Fourche Field Station are similar in scope and character to the experiments begun at the same time at the Huntley Field Station near Huntley, Mont., and at the Scotts Bluff Field Station near Mitchell, Nebr., and described in former publications.[1]

The main purpose of these rotations was to obtain information that would be useful to persons engaged in crop production on the project and on other irrigated areas where the soil and climatic conditions are comparable. This information was sought through (1) comparing yields from continuously cropped plots with those obtained when similar crops are grown in a rotation with other crops for two or more years; (2) comparing the effect on the yields of various crop sequences in 2-year and 3-year rotations, but otherwise having no special treatment; (3) ascertaining the effect of alfalfa included in the rotation with various crops when maintained two as compared with three years before being plowed under; (4) ascertaining how effectively crop yields may be maintained or improved by applications of stable manure in 2-year and 3-year rotations, all compared with similar rotations but not so treated; (5) ascertaining the extent that crop yields may be stimulated by pasturing alfalfa and harvesting the corn crop with hogs as compared with similar rotations where the crops are harvested in the usual manner.

In addition to the foregoing more important features, information has been obtained on (1) the value of sweetclover when pastured as a substitute for alfalfa; (2) the effect of rye when grown as a green-manure crop; (3) the effect on crop yields when red clover is substituted for alfalfa or sweetclover; and (4) the effect of annual applications of manure on the yield of alfalfa.

The rotations comprising the first series were started in 1912 and consisted of 32 different cropping systems. As information on the effects of these different cropping methods accumulated it was found desirable to add to this number. Since that year eight additional rotations have been included in order that advantage might be taken of new developments. Plot 10, barley continuously, was added in 1914; rotation 69 was included in the series in 1915, and rotation 71 in 1916. In 1917 rotations 34, 35, 46, and 64 were added. However, yields of oats and potatoes are not recorded for that year, as the crops were not grown until the following year, 1918. Rotation 37 was incorporated in the series in 1923.

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[1] SCOFIELD, C. S., and HOLDEN, J. A. IRRIGATED CROP ROTATIONS IN WESTERN NEBRASKA. U. S. Dept. Agr. Tech. Bul. 2, 26 p., illus. 1929.
HASTINGS, S. H., and HANSEN, D. IRRIGATED CROP ROTATIONS IN SOUTHERN MONTANA. U. S. Dept. Agr. Tech. Bul. 144, 32 p., illus. 1929.

SCHEDULE OF ROTATIONS

The various rotations as reported in this circular are as follows:

Crops grown continuously on the same land: (1) Oats, (2) sugar beets, (3) spring wheat, (4) potatoes, (5) winter wheat, (6) corn, (8–a) alfalfa, (8–b) alfalfa (manure), (9) flax, and (10) barley.

The 2-year rotations are as follows: (16) Corn, oats; (18) spring wheat, sugar beets; (20) potatoes, sugar beets; (21) potatoes (manure), sugar beets; (22) oats, sugar beets; (23) oats (manure), sugar beets; (24) potatoes, oats; (25) potatoes, oats (manure); (26) potatoes, corn; (27) potatoes, oats (rye seeded in oat stubble and plowed under the following spring); and (28) spring wheat, oats.

The 3-year rotations consist of the following: (30) Potatoes, oats, sugar beets; (31) potatoes, oats (manure), sugar beets; (32) corn, oats, sugar beets; (34) potatoes, sugar beets, oats; (35) potatoes, sugar beets, oats (manure); and (37) corn, barley (sweetclover seeded with the barley), sweetclover (harvested with cows).

There are four 4-year rotations, all including two years of alfalfa, with crops and sequences as follows: (40) Potatoes, sugar beets, alfalfa, alfalfa; (42) oats, sugar beets, alfalfa, alfalfa; (44) potatoes, oats, alfalfa, alfalfa; (46) sugar beets, oats, alfalfa, alfalfa; and (48) spring wheat, oats, alfalfa, alfalfa.

The 6-year rotations reported upon in the series comprise the following: (60) Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa; (61) potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa; (62) corn, oats, sugar beets, alfalfa, alfalfa, alfalfa; (64) potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa; (65) corn (harvested with hogs), flax, oats, alfalfa, alfalfa, alfalfa (harvested with hogs third year); (66) sugar beets, flax, barley, corn, winter wheat (red clover seeded with the wheat), red clover; (69) corn (harvested with hogs), corn (harvested with hogs), oats, alfalfa, alfalfa, alfalfa (harvested with hogs third year); and rotation (71) corn (harvested with lambs), sugar beets, oats, alfalfa, alfalfa, alfalfa (harvested with sheep third year).

These rotations are so arranged that each crop in each rotation is grown every year. To carry out this plan it is necessary to have as many plots as there are years in the cycle for each rotation. With this method it is possible each year to compare the yields from the same crops grown in each of the different rotations.

For convenience of reference the following is a list of the various rotations arranged in numerical order:

CROPS GROWN CONTINUOUSLY ON THE SAME PLOTS

1. Oats.
2. Sugar beets.
3. Spring wheat.
4. Potatoes.
5. Winter wheat.
6. Corn.

8–a. Alfalfa.
8–b. Alfalfa (manure).

9. Flax.
10. Barley.

2-YEAR ROTATIONS

16. Corn, oats.
18. Spring wheat, sugar beets.
20. Potatoes, sugar beets.
21. Potatoes (manure), sugar beets.
22. Oats, sugar beets.
23. Oats (manure), sugar beets.
24. Potatoes, oats.
25. Potatoes, oats (manure).
26. Potatoes, corn.
27. Potatoes, oats (rye).
28. Spring wheat, oats.

3-YEAR ROTATIONS

30. Potatoes, oats, sugar beets.
31. Potatoes, oats (manure), sugar beets.
32. Corn, oats, sugar beets.
34. Potatoes, sugar beets, oats.
35. Potatoes, sugar beets, oats (manure).
37. Corn, barley (seeded with sweetclover), sweetclover (harvested with cows).

4-YEAR ROTATIONS

40. Potatoes, sugar beets, alfalfa (two years).
42. Oats, sugar beets, alfalfa (two years).
44. Potatoes, oats, alfalfa (two years).
46. Sugar beets, oats, alfalfa (two years).
48. Spring wheat, oats, alfalfa (two years).

6-YEAR ROTATIONS

60. Potatoes, oats, sugar beets, alfalfa (three years).
61. Potatoes, oats (manure), sugar beets, alfalfa (three years).
62. Corn, oats, sugar beets, alfalfa (three years).
64. Potatoes, sugar beets, oats, alfalfa (three years).
65. Corn (harvested with hogs), flax, oats, alfaifa (three years, pastured with hogs third year).
66. Sugar beets, flax, barley, corn, winter wheat, red clover.
69. Corn (two years harvested with hogs), oats, alfalfa (three years, harvested with hogs third year).
71. Corn (harvested with lambs), sugar beets, oats, alfalfa (three years, harvested with sheep third year).

The field plan of the various rotations is shown in Figure 1, and a view of some of the plots is given in Figure 2.

CULTURAL PRACTICES

In conducting these investigations the methods adopted in performing the various cultural operations were in keeping with the better practices used in the locality. In order that the yields from the same crop in different rotations would be directly comparable, all were planted as nearly as possible at the same time and of the same variety each year. The treatment the plots received was as nearly identical as conditions permitted; all crops were harvested at the same time and otherwise received identical treatment in so far as conditions permitted.

Irrigation water was applied so as to meet adequately the varying demands of different crops, the aim being to maintain the supply of soil moisture at the optimum for plant growth. Alfalfa, grain, flax, and other drilled or broadcast crops were irrigated by the flooding method, while row crops were furrow irrigated.

All plots to be planted the following year to a cultivated crop were plowed about 8 inches deep and left rough throughout the winter. Alfalfa to be followed by another crop was plowed in the fall and the ground worked with a spring-tooth harrow or duck-foot cultivator to kill as many of the plants as possible. Where grain follows an uncultivated crop the land was fall plowed and left untouched throughout the winter. Plots preceded by a cultivated crop and to be planted to grain or alfalfa were not plowed but were disked or gone over with a duck-foot cultivator, leveled, and harrowed before planting. In the case of late-planted crops, like corn, flax, and potatoes, the duck-foot cultivator was used again and the land harrowed just before planting. Where barnyard manure is used it is applied at the rate of 12 tons per acre in the fall before the land is plowed.

Oats were seeded about the middle of April at the rate of 80 pounds per acre. Winter wheat was seeded the latter part of September at the rate of 80 pounds per acre. The same rate of seeding was used for spring wheat, and the seeding date was as near April 15 as possible.

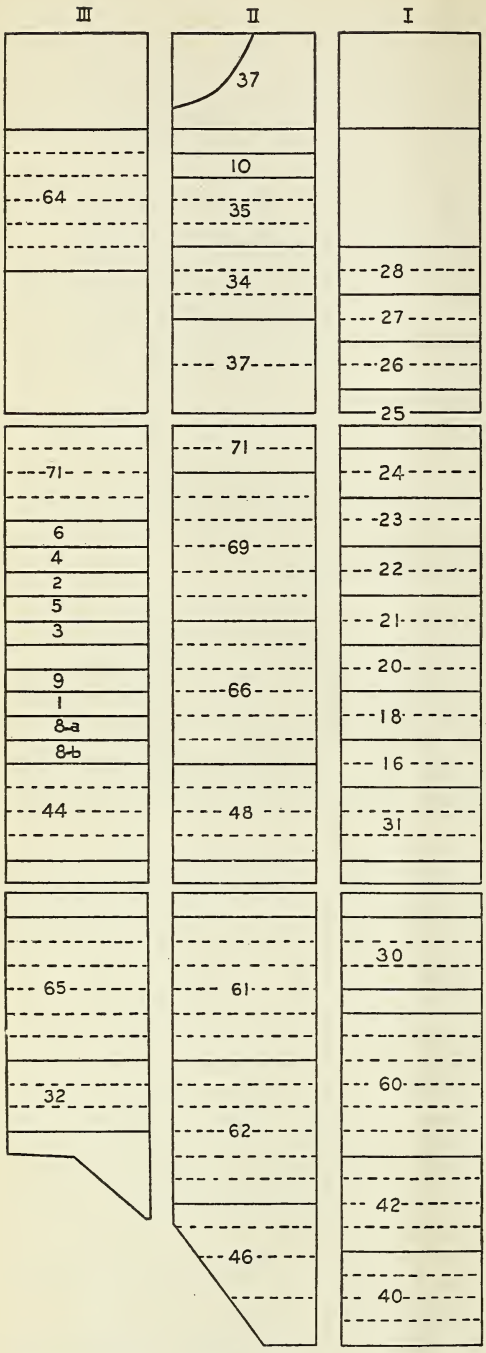

FIGURE 1.—Plan of irrigated rotation plots at the Belle Fourche Field Station

Barley was sown at the same time as spring wheat and at the rate of 100 pounds per acre. Alfalfa and sugar beets were planted the latter part of April or early in May; corn and flax when danger of frost was past, or about May 20, and potatoes about June 1. Rye in the 2-year rotation No. 27 was disked in the oat stubble immediately after the oats were harvested, which was usually the latter part of August. The rye was plowed under the following spring about the middle of May, shortly before the potatoes were to be planted. In rotation 37 sweetclover was seeded in with the barley, the clover pastured the following year, and the land plowed in the fall. Stable manure was applied to the plot continuously in alfalfa (8–b) at the rate of 12 tons per acre after the last fall cutting.

Throughout the 18-year period that these investigations have been in progress there has been a wide variation in the climatic conditions, but there is no reason for believing that this factor alone, which has an important bearing on crop yields generally, is more adverse in western South Dakota than in many other sections. However, where there are gumbo soils similar to those found on the Belle Fourche Field Station it has been apparent that the influence of climatic conditions in certain seasons has had a profound effect on crop yields,

notably more definite than would be the case if the soil were materially less refractory. Such soils warm up slowly in the spring, can not be worked properly except when moisture conditions are favorable, and do not dry rapidly. Cool, damp springs not infrequently have so delayed planting or retarded crop growth that crop yields have been markedly depressed. This is apparent when a comparison is made of the detailed crop yields over the entire 18-year period in the following tables. Insect pests and plant diseases have also been a factor. These hazards have not always operated uniformly on all plots. Such adverse conditions have at times resulted in a lack of uniformity in the stand of plants of certain crops during the same season on the different plots. Obviously such factors have caused fluctuations in crop yields in the rotations which could not be attributed in all cases to the differences in the rotational practices. When such variations have occurred and could be definitely recognized and at the same

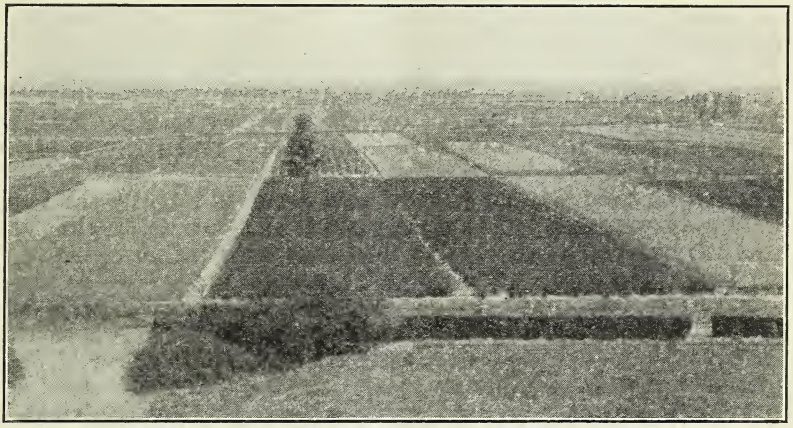

FIGURE 2.—View of part of the rotation plots at the Belle Fourche Field Station, looking east, with cropping systems 8-a and 8-b, Series III, in the center foreground

time had a tendency to distort the results, these facts are mentioned in the text.

CROP YIELDS IN DETAIL

In presenting the results from the various rotations for the 18-year period it has seemed desirable to include in the first series of tables the basic facts in detail as to the yields obtained. This method affords an opportunity of observing and comparing in a number of ways the effects of the different crop sequences and treatments to which the crops under consideration have been subjected. Also, as the yearly results are given, it permits the reader to observe the annual fluctuations in yields. Without a detailed presentation of the data where the variations in yields may be observed there is danger that erroneous conclusions may be drawn. Where it has been definitely evident that accidental injuries have been sustained during certain seasons by the various crops recognition is taken of the fact in the discussion of the results. However, it is obvious that in accumulating such a large number of individual yearly crop yields for an 18-year-period account can not be taken of all factors that may have influenced the results that can not be attributed to the

rotational treatments the crops have received. When the yields are summarized and compared, however, as has been done in later tables, it is believed that such individual inconsistencies as have occurred have been absorbed largely by averaging several units, to the end that the results recorded reflect the normal differencies which should be expected under average farm conditions in the Belle Fourche area.

Each of the tables giving the crop yields in detail is devoted to a single crop. The number of each rotation is given, together with the yields per acre for each year for that rotation. The annual mean for all rotations, together with the maximum and range for the 18-year period, is computed. To afford an opportunity to observe the trend of yields, the 18 years of recorded results are divided into three 6-year periods, namely, 1912 to 1917, 1918 to 1923, and 1924 to 1929.

OATS

The yields of oats are given in Table 1. Rotations 34, 35, 46, and 64 were not included as a part of the series until 1918. Rotation 69 was not started until 1915 and 71 until 1916. Consequently the yields for these rotations do not appear in the column giving the mean yield for the first 6-year period, 1912 to 1917. No total crop failure of oats occurred during any year with any rotation, although in some instances there were very low yields, particularly in certain rotations in 1920.

The largest mean annual yield of oats occurred in 1915, the fourth year of the experiment. The mean yield of all rotations for the 6-year period 1912 to 1917 is also higher than that recorded for either of the other two. The explanation for this condition appears to be largely the original productivity of the soil. For the first few years after being brought under irrigation lands similar to those where these tests were conducted produced relatively high yields of cereal crops. Under such a wide range of cropping conditions as those under consideration there has appeared to be a tendency for the yields to decline in certain instances. This is distinctly apparent in the plot continuously cropped and in certain of the untreated rotations, notably when the first 6-year period is compared with the last two. The lowest yield recorded is from untreated rotation 28, in which wheat is the companion crop. The lowest annual mean yield occurred in 1920, which was a very unfavorable season for oat production, because of rust. There is a wide fluctuation in the yields obtained that year also. This condition is apparent when the yields of rotations 32, 44, and 62 are compared with others in the series. The injury from rust on these plots as compared with the others was very severe, apparently due to their location near a buckthorn hedge, which has since been removed. The next lowest average yield was harvested in 1927. The precipitation during the spring months of that year was abnormally heavy, preventing seeding until June 4, more than a month later than is considered desirable. Later in the growing season rust appeared, injuring the crop to such an extent that such differences in the yields as occurred in most instances can not be attributed to the effect of crop sequences or the treatments applied.

TABLE 1.—*Acre yields of oats (bushels) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
1–a	67.4	48.8	103.3	82.5	41.6	57.3	55.6	57.4	12.5	26.8	23.8
16	55.3	44.8	74.5	65.3	49.2	42.3	57.8	35.6	28.6	45.0	31.6
22	57.4	45.0	77.5	99.1	57.4	71.5	86.8	48.6	36.8	45.4	53.9
23	55.3	44.4	74.8	104.5	43.8	76.0	91.9	50.0	34.4	47.3	66.1
24	47.6	44.0	73.6	112.0	59.0	72.9	89.6	60.3	49.2	56.8	53.6
25	41.1	33.8	52.7	104.0	54.6	74.4	90.6	58.9	49.5	60.0	71.1
27	43.3	39.1	77.7	101.3	62.6	75.4	92.1	55.5	41.4	53.4	64.0
28	35.4	31.9	26.3	50.0	27.1	40.4	36.3	28.6	15.0	26.9	32.6
30	40.7	46.8	93.5	106.9	56.0	65.9	70.4	37.0	37.0	60.8	44.3
31	65.6	51.0	90.0	104.0	71.5	75.6	80.8	54.1	46.0	59.6	57.9
32	43.7	30.5	92.2	72.5	62.5	41.4	53.6	24.5	7.5	42.3	49.8
34	------	------	------	------	------	------	73.9	53.9	36.9	41.6	62.6
35	------	------	------	------	------	------	82.9	44.9	39.2	43.8	64.8
42	61.5	26.1	61.1	74.6	28.7	35.5	48.3	16.5	22.5	33.9	47.1
44	60.5	54.5	109.6	116.5	80.3	71.9	83.4	60.5	6.9	41.4	23.4
46	------	------	------	------	------	------	56.0	17.9	25.5	30.6	49.8
48	80.0	54.0	105.3	118.5	58.4	69.4	86.3	57.0	13.0	31.4	43.4
60	50.0	35.0	94.6	108.9	49.8	51.8	77.8	30.1	27.8	54.5	53.0
61	54.6	39.0	100.4	114.1	82.8	49.0	81.1	39.5	22.6	37.8	51.8
62	45.6	28.5	103.7	79.8	63.6	45.2	66.8	19.1	9.2	34.6	47.3
64	------	------	------	------	------	------	71.2	34.9	34.3	33.3	69.4
65	54.0	28.9	84.8	117.1	73.8	73.4	82.9	50.1	11.1	24.4	49.0
69	------	------	------	81.4	57.4	60.1	89.8	38.8	29.1	56.5	53.6
71	------	------	------	------	42.0	60.0	92.6	54.8	23.7	30.6	64.1
Annual mean	53.3	40.3	83.1	95.4	56.1	60.5	74.9	42.9	27.5	42.4	51.2
Maximum	80.0	54.5	109.6	118.5	82.8	76.0	92.6	60.5	49.5	60.8	71.1
Range	44.6	28.4	83.3	68.5	55.7	40.5	56.3	44.0	42.6	36.4	47.7

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean, 1918–1923	Mean, 1924–1929
1–a	50.5	51.0	46.4	36.5	25.3	45.2	32.5	66.8	37.8	39.5
16	50.0	60.2	55.1	37.7	23.1	53.7	50.0	55.2	41.4	46.6
22	55.8	60.8	61.6	60.6	33.8	73.7	63.7	68.0	54.6	59.0
23	66.5	67.5	58.3	65.5	33.8	83.9	68.7	66.5	59.4	63.0
24	68.3	71.1	63.6	61.5	26.0	70.5	61.2	68.2	63.0	59.0
25	67.5	80.9	75.8	65.9	37.1	95.7	87.5	60.1	66.3	73.8
27	60.5	60.0	63.5	56.2	35.0	88.7	56.2	66.6	61.2	59.9
28	20.5	20.5	12.8	8.5	20.6	16.1	23.7	35.2	26.7	17.0
30	57.0	55.3	62.1	56.7	31.3	90.0	53.7	68.3	51.1	58.2
31	70.3	69.4	76.3	68.2	42.5	89.5	66.2	76.3	61.5	68.7
32	38.3	37.3	38.4	41.9	28.1	46.1	58.7	57.1	36.0	41.8
34	55.0	50.0	42.5	77.2	36.3	52.6	45.0	------	54.0	50.6
35	63.3	52.5	44.4	57.5	37.5	61.6	51.2	------	56.5	50.8
42	51.5	38.8	59.3	45.6	26.3	47.6	62.5	47.9	36.6	46.7
44	58.8	72.9	90.4	84.4	25.6	92.1	86.2	82.2	45.7	75.3
46	51.5	58.4	79.0	53.5	18.8	76.6	101.2	------	38.6	64.6
48	56.3	72.4	89.4	67.6	20.0	73.4	81.2	80.9	47.9	67.3
60	55.6	75.6	66.5	61.9	28.8	106.5	71.2	65.0	49.8	68.4
61	59.3	67.3	60.9	71.0	35.6	107.5	85.0	73.3	48.7	71.2
62	48.5	55.3	57.4	45.0	27.5	77.5	55.0	61.1	37.6	53.0
64	59.0	48.8	56.4	60.0	24.4	68.2	68.7	------	50.4	54.4
65	55.0	69.3	66.0	51.7	21.3	66.9	83.7	72.0	45.4	59.8
69	64.5	56.5	86.4	87.7	19.0	91.6	86.2	--- ---	55.4	71.2
71	60.3	48.5	70.6	62.5	20.3	87.0	107.5	------	54.4	66.1
Annual mean	56.0	58.3	61.8	57.7	28.3	73.4	66.9	65.0	49.2	57.7
Maximum	70.3	80.9	90.4	87.7	42.5	107.5	107.5	------	------	------
Range	49.8	60.4	77.6	79.2	23.7	91.4	83.8	------	------	------

SUGAR BEETS

The yields of sugar beets are given in Table 2. Rotations 34, 35, 46, and 64 were not incorporated as a part of the series until 1917, and No. 71 was not included until 1916, which account for certain omissions in these rotations for the first 6-year period. Owing to unfavorable weather conditions experienced in the spring of 1919, such a poor stand resulted even after the second attempt that measurable yields were not harvested in the fall.

TABLE 2.—*Acre yields of sugar beets (tons) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
2-a	5.4	6.0	6.9	4.6	6.8	9.1	6.7	------	9.6	6.6	10.1
18	7.3	7.8	9.3	8.8	5.8	11.7	8.0	------	5.6	7.5	8.7
20	7.0	10.7	11.3	12.2	9.7	15.3	10.9	------	9.3	15.7	14.2
21	6.9	8.8.	14.6	16.0	12.1	18.6	13.2	------	11.2	17.5	18.8
22	7.6	7.6	12.3	9.1	8.1	12.7	8.6	------	9.1	11.9	13.3
23	5.7	8.3	10.6	11.8	9.6	20.9	11.6	------	11.6	16.5	17.4
30	7.4	9.0	10.7	7.3	4.6	7.4	7.3	------	5.0	8.4	11.2
31	8.4	9.3	14.2	13.2	8.2	15.3	12.2	------	7.3	9.2	17.3
32	8.6	6.5	8.7	6.8	4.0	7.6	6.0	------	4.6	6.2	9.7
34	------	------	------	------	------	11.7	14.8	------	8.6	16.8	17.1
35	------	------	------	------	------	17.4	14.5	------	11.5	15.0	19.9
40	8.2	8.5	12.8	11.0	8.8	14.2	11.0	------	8.9	11.9	13.8
42	9.5	8.7	11.1	7.0	4.2	10.0	8.9	------	6.8	8.5	12.2
46	------	------	------	------	------	12.8	6.6	------	6.3	4.5	7.2
60	8.4	8.0	11.2	9.4	7.2	12.7	13.7	------	8.4	8.9	13.5
61	7.1	6.0	12.7	10.9	10.4	15.7	13.8	------	7.4	12.7	17.3
62	7.5	7.0	10.7	8.3	4.9	8.5	9.9	------	7.2	5.6	10.1
64	------	------	------	------	------	12.0	12.3	------	8.2	11.4	15.9
66	10.4	5.5	10.5	5.1	2.9	6.5	7.2	------	6.2	3.7	4.2
71	------	------	------	------	5.8	15.8	14.3	------	6.9	11.2	20.8
Annual mean	7.7	7.8	11.2	9.4	7.1	12.8	10.8	------	8.0	10.5	13.6
Maximum	10.4	10.7	14.6	16.0	12.1	20.9	14.8	------	11.6	17.5	19.9
Range	5.0	5.2	7.7	11.4	9.2	14.4	8.8	------	7.0	13.8	15.7

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean,[1] 1918–1923	Mean, 1924–1929
2-a	8.4	7.5	9.5	7.1	3.6	5.1	2.5	6.5	8.3	5.9
18	9.6	7.2	9.9	6.6	5.5	8.0	7.2	8.5	7.9	7.4
20	15.5	14.5	13.7	14.1	8.4	12.3	13.0	11.0	13.1	12.7
21	20.6	17.1	19.1	22.8	10.2	19.2	17.0	12.8	16.3	17.6
22	14.2	10.1	15.9	14.3	8.2	10.4	9.7	9.6	11.4	11.4
23	20.3	13.1	19.9	16.8	11.7	15.0	19.1	11.2	15.5	15.9
30	8.6	8.5	8.4	7.5	5.1	5.8	5.4	7.7	8.1	6.8
31	14.8	13.4	14.3	14.5	10.1	13.8	11.6	11.4	12.2	13.0
32	7.7	5.0	9.0	5.5	5.3	6.0	5.4	7.0	6.8	6.0
34	15.6	13.1	17.4	12.2	8.3	12.4	13.1	------	14.6	12.8
35	16.2	15.0	20.7	14.9	9.5	14.0	14.9	------	15.4	14.8
40	15.7	13.7	14.1	12.2	8.3	12.6	16.0	10.6	12.3	12.8
42	11.1	8.3	10.6	10.1	6.3	11.0	8.2	8.4	9.5	9.1
46	9.7	4.2	9.8	11.3	3.5	8.3	6.3	------	6.9	7.2
60	13.0	10.8	13.0	10.4	7.4	11.0	9.5	9.5	11.5	10.4
61	16.4	10.6	17.3	12.0	11.8	17.6	15.2	10.5	13.5	14.1
62	12.5	6.8	10.8	10.7	7.3	9.9	9.0	7.8	9.1	9.1
64	14.4	14.3	16.4	8.9	8.5	14.0	13.4	------	12.4	12.6
66	4.5	3.5	6.3	8.8	2.7	4.3	1.2	6.8	5.2	4.5
71	14.3	13.6	22.7	15.7	9.6	18.0	16.5	------	13.5	16.0
Annual mean	13.2	10.5	13.9	11.8	7.6	11.4	10.7	9.3	11.2	11.0
Maximum	20.6	17.1	20.7	22.8	11.8	19.2	19.1	------	------	------
Range	16.1	13.6	14.4	17.3	9.1	14.9	17.9	------	------	------

[1] Exclusive of 1919.

The lowest mean annual yield occurred in 1916, when only 7.1 tons per acre were harvested. This was due largely to injury from an insect known locally as the beet louse. The yields from rotations 30, 40, 42, and 62 were further reduced by injury from seepage. The next lowest mean annual yield was that harvested in 1927, which was attributed to unfavorable weather conditions in the spring, necessitating late planting, and to a hailstorm occurring early in July, which so severely injured the young plants that they never fully recovered. The highest mean annual yield of 13.9 tons per acre was harvested in 1925. In 1926 sugar beets in rotation 21 produced 22.8 tons per acre, the largest yield of any rotation for the

18-year period. This is a 2-year rotation where potatoes are the companion crop and stable manure is applied preceding the sugar beets. Contrary to the results recorded for oats the mean annual yields for 1912, 1913, 1914, and 1915 indicate that sugar beets on new land the first few years after it is brought under irrigation do not produce as satisfactorily as during later years when the crop is grown in well-planned rotations. Aside from 1916 and 1927, when crop injury was sustained by reason of either unfavorable climatic conditions or insect injury, consistently high yields are recorded for manured rotations 21, 23, 31, and 35, indicating the value of such treatment. Even slightly more favorable effects are apparent in No. 71, which is a 6-year rotation, including three years of alfalfa, which is harvested with sheep the third year, and one corn crop also harvested with sheep.

The lowest average yields recorded since 1919 were those harvested in 1927, and the next lowest were yields harvested from the 1920 crop. Owing to wet weather occurring at the proper planting time, seeding was materially delayed in 1920. Also, after the beets were up frequent showers occurred which maintained the soil moisture at a point higher than is desirable to promote a satisfactory growth of the young plants.

The yields in 1929 are worthy of special consideration. As indicated by the average the yields for this season were only slightly below normal. The seasonal and other conditions appeared to be favorable to bring out the differences to be expected from the various rotational practices. The average yield from the 10 rotations that have had a tendency toward low production during the last few years was 6.7 tons per acre. On the other hand the 10 rotations that have indicated by their yields the more desirable crop sequences and treatments returned for that year an average yield of 15 tons per acre, or a difference of 8.3 tons per acre in favor of the better cropping programs.

POTATOES

In Table 3 are given the annual yields of potatoes as this crop appears in the different rotations. Rotations 34, 35, and 64 were not included as a part of the series until 1918. Owing to unfavorable weather conditions following the planting of potatoes in the spring of 1920, the stand obtained was negligible, so that measurable yields were not harvested. The lowest mean annual yield of 48.2 bushels per acre was harvested in 1912, the first year of the experiments. Comparable low yields are also recorded for 1919, 1927, and again in 1929. These low yields were all attributed to the unfavorable weather occurring after planting, causing a poor stand. The injury sustained by the different plots in the various rotations in 1927 and again in 1929 was of such magnitude and so variable that the yields usually do not reflect the differences that would be expected under more normal conditions. The yields in 1923 as a rule were low. This was caused by unseasonably cool wet weather occurring in the fall months and causing severe loss from rot. The seasonal fluctuations in the yield of potatoes are often large, as is apparent in this table. Heavy gumbo soils, such as are found where these investigations are being conducted, rarely produce large yields of potatoes,

and the yields from season to season often fluctuate within wide limits, although when weather conditions are favorable satisfactory results may be obtained, particularly when the crop is grown in a well-planned rotation. When the past 12-year mean yields for such rotations as 21, 25, 31, and 44 are considered, these results indicate that over a series of years a farmer may expect returns justifying the inclusion of potatoes in the planting program if the crop is grown in identical or comparable cropping systems.

TABLE 3.—*Acre yields of potatoes (bushels, field run) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920[1]	1921	1922
4	43.4	131.6	131.2	142.3	175.0	192.7	168.0	36.3	-------	105.3	121.3
20	70.9	128.0	86.4	102.0	157.0	132.7	166.7	57.3	-------	95.3	120.0
21	59.3	133.3	117.2	192.0	169.7	190.0	215.7	68.7	-------	243.3	244.0
24	13.5	109.3	112.0	111.3	151.3	120.3	191.3	56.0	-------	144.0	151.3
25	41.3	95.3	101.2	168.0	162.0	134.7	236.0	52.7	-------	122.7	194.0
26	34.4	120.6	116.0	112.0	149.0	161.3	187.0	72.7	-------	166.7	120.7
27	25.8	114.6	94.4	66.7	154.3	127.9	24.3	33.3	-------	171.3	80.7
30	49.9	74.3	68.0	58.7	166.0	139.0	168.2	96.0	-------	118.0	163.3
31	53.8	90.0	139.3	137.3	188.0	205.0	231.3	65.6	-------	240.0	232.0
34	-------	-------	-------	-------	-------	-------	179.1	82.0	-------	177.3	156.0
35	-------	-------	-------	-------	-------	-------	162.7	82.0	-------	242.0	210.7
40	74.8	88.0	96.0	94.0	129.2	124.0	203.3	70.7	-------	175.3	168.0
44	56.0	176.6	127.2	144.0	149.0	170.0	152.7	78.7	-------	175.3	167.3
60	88.7	97.3	105.2	105.3	118.7	108.0	170.0	82.3	-------	145.3	164.7
61	14.4	139.3	112.4	115.3	123.7	130.4	164.7	66.7	-------	134.0	156.7
64	-------	-------	-------	-------	-------	-------	144.7	13.3	-------	117.3	130.0
Annual mean	48.2	115.2	108.2	119.1	153.3	148.9	172.9	63.4	-------	160.8	161.3
Maximum	88.7	176.6	139.3	192.0	188.0	205.0	236.0	96.0	-------	243.3	244.0
Range	75.2	102.3	71.3	133.3	69.3	97.0	211.7	82.7	-------	148.0	163.3

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean,[2] 1918–1923	Mean, 1924–1929
4	80.7	176.0	214.0	110.0	78.7	129.3	47.2	136.0	102.3	125.9
20	99.0	95.3	134.7	116.7	37.3	117.7	39.4	112.8	107.7	90.2
21	136.7	190.0	242.7	178.0	40.0	193.3	62.0	143.6	181.7	151.0
24	84.0	206.0	185.8	184.0	39.3	143.3	47.0	103.0	125.3	134.2
25	135.3	241.7	237.3	218.0	78.1	183.3	55.5	117.1	148.1	169.0
26	79.3	192.0	224.3	170.0	48.7	163.3	31.2	115.6	125.3	138.3
27	73.3	133.3	150.7	60.0	45.3	180.0	9.0	97.3	76.6	96.4
30	61.3	171.3	189.3	153.3	38.0	153.3	56.8	92.7	121.4	127.0
31	106.3	254.0	226.7	208.7	109.3	193.3	90.1	135.6	175.0	180.4
34	141.3	200.0	195.0	134.0	76.0	161.3	64.3	-------	147.1	138.4
35	150.3	280.6	295.3	156.0	123.3	252.0	31.5	-------	169.5	189.8
40	158.3	177.3	182.0	174.7	56.7	179.3	57.3	101.0	155.1	137.9
44	159.0	202.0	299.3	198.0	133.3	224.0	46.1	137.1	146.6	183.8
60	79.3	174.7	222.0	180.0	46.0	182.7	59.0	103.9	128.3	144.1
61	88.0	176.0	219.3	129.3	42.0	190.0	42.7	105.9	122.0	133.2
64	100.0	171.3	139.3	140.7	101.3	190.0	51.3	-------	101.1	132.3
Annual mean	108.3	190.1	209.9	157.0	68.3	177.3	49.4	115.5	133.3	142.0
Maximum	159.0	280.6	299.3	218.0	133.3	252.0	90.1	-------	-------	-------
Range	97.7	185.3	164.6	158.0	96.0	134.3	81.1	-------	-------	-------

[1] No measurable yields.

[2] Exclusive of 1920.

The highest annual mean yield of potatoes for the 18-year period for all rotations was harvested in 1925. This was also the year when rotation 44 produced 299.3 bushels per acre, the largest yield recorded from any of the rotations since the investigations were started. Consistently satisfactory yields are apparent from manured rotations 21, 25, 31, and 35, except during the years when climatic conditions were so unfavorable that poor stands occurred or the losses were

severe because of rot. On the other hand, relatively low yields have resulted from rotation 20, a 2-year rotation with sugar beets. Unsatisfactory yields are apparent when those from rotation 27 are observed. This rotation includes potatoes and oats with rye seeded in the oat stubble in the fall and plowed under the following spring shortly before the planting of the potatoes.

CORN

The corn yields, as recorded in Table 4, are divided into two sections, the first part being from the seven rotations where the crop is harvested in the usual manner and the second from three rotations where the corn crops are harvested by livestock and the yields estimated. Corn was not planted on continuously cropped plot 6 in 1912. Yields from rotation 37 are for the last seven years, as it was not included as a part of the series until 1923. In 1915 rotation 69 was added, and 71 the following year.

In the case of the four plots harvested by livestock the method of arriving at the acre yield was as follows: The stand was determined by an actual count of all the stalks on the plot. Then the ears were harvested from 100 stalks which were selected systematically on the basis of 100. If a plot contained 1,200 stalks the ears from every twelfth stalk were harvested and weighed, and the yield was computed accordingly. The consistency of the yields each season from all rotations indicate that corn may be expected to return fairly satisfactory yields every season and that the crop is less subject to injury from either unfavorable seasonal conditions or insect and disease pests than are the cereals, sugar beets, or potatoes.

The highest yield harvested from any of the rotations where actual yields were obtained during the 18-year period was 63.9 bushels per acre from rotation No. 66 in 1922, and the lowest 14.7 bushels from continuously cropped plot No. 6 in 1927. The lowest mean annual yield of 27.3 bushels per acre was recorded in 1927. This was due to the fact that the weather for the season was cold and wet followed by an early frost in the fall. The rotation producing the highest yield for the last 6-year period is No. 37, which includes corn, barley, and sweetclover pastured.

The corn yields from the rotations where the crop is harvested by livestock and estimates only are obtained are consistently higher than those obtained from the other cropping systems. A yield of 73.9 bushels per acre from rotation 69–a in 1925 was the largest of either series. This plot returned the largest yield for the last 6-year period also. The mean yield for these rotations for the last six years is 51.7 bushels per acre, or 15.3 bushels more than the mean yield for the same period for the seven cropping systems in the first series. These results indicate that harvesting certain crops with livestock has a favorable influence in increasing the yields of corn.

TABLE 4.—*Acre yields of corn (bushels) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean, 1918–1923	Mean, 1924–1929
6	------	53.7	51.1	32.1	42.6	48.0	48.0	44.5	35.3	49.9	34.1	43.0	19.7	47.0	42.1	14.7	49.0	37.1	[1]45.5	42.5	34.9
16	37.0	33.1	48.8	28.8	37.5	39.7	38.3	29.3	28.1	38.4	40.0	44.0	23.5	39.5	34.5	27.3	36.7	21.6	37.5	36.4	30.5
26	24.0	21.6	44.4	31.6	44.3	44.1	46.5	44.7	31.0	53.1	29.9	45.0	28.9	43.4	36.2	15.5	39.3	27.7	35.0	41.7	31.8
32	30.0	30.5	32.5	28.5	40.5	49.6	47.0	42.3	38.4	36.3	33.1	40.0	29.5	34.6	36.3	30.0	35.2	15.8	35.3	39.5	30.2
37	------	------	------	------	------	------	------	------	------	------	------	54.5	36.7	50.5	55.4	35.8	54.6	47.4	------	------	46.7
62	28.5	32.3	44.4	32.2	42.8	42.6	40.0	38.4	29.0	34.1	40.5	50.0	41.9	39.8	48.7	39.0	43.7	33.9	37.1	38.7	41.2
66	24.0	43.0	39.4	43.2	46.9	53.8	31.8	27.7	39.0	40.3	63.9	51.0	25.4	38.9	50.0	29.1	50.7	41.5	41.7	42.3	39.3
Annual mean	28.7	35.7	43.4	32.7	42.4	46.3	41.9	37.8	33.5	42.0	40.3	46.8	29.4	42.0	43.3	27.3	44.2	32.1	38.7	40.2	36.4
Maximum	37.0	53.7	51.1	43.2	46.9	53.8	48.0	44.7	39.0	53.1	63.9	54.5	41.9	50.5	55.4	39.0	54.6	47.4	------	------	------
Range	13.0	32.7	18.6	14.7	9.4	14.1	16.2	17.0	10.9	19.0	34.0	14.5	22.2	15.9	20.9	24.3	19.4	31.6	------	------	------
HARVESTED WITH LIVESTOCK AND YIELDS ESTIMATED																					
65	28.7	34.0	34.8	40.6	59.1	67.4	55.8	40.9	42.8	63.7	68.1	64.7	32.0	68.9	56.3	46.4	58.7	50.9	44.1	56.0	52.2
69-a	------	------	------	33.9	50.4	57.2	56.7	36.5	42.5	47.1	64.3	49.5	46.0	73.9	58.8	42.9	53.4	55.9	------	49.4	55.2
69-b	------	------	------	34.1	45.0	53.6	56.7	43.4	44.7	60.4	73.5	56.8	28.0	62.6	58.8	34.3	68.0	49.4	------	55.9	50.2
71	------	------	------	------	52.0	57.1	55.0	30.0	42.0	53.0	60.0	59.1	38.0	45.1	49.7	45.7	64.9	50.9	------	49.9	49.1
Annual mean	28.7	34.0	34.8	36.2	51.6	58.8	56.1	37.7	43.0	56.1	66.5	57.5	36.0	62.6	55.9	42.3	61.3	51.8	44.1	52.8	51.7
Maximum	------	------	------	40.6	59.1	67.4	56.7	43.4	44.7	63.7	73.5	64.7	46.0	73.9	58.8	46.4	68.0	55.9	------	------	------
Range	------	------	------	6.7	14.1	13.8	1.7	13.4	2.7	16.6	13.5	15.2	18.0	28.8	9.1	12.1	14.6	6.5	------	------	------

[1] 5-year mean—no corn planted in 1912.

WHEAT

Spring wheat was included in the cropping system of three rotations, and one plot was continuously cropped. The yields are reported in Table 5. Low yields are apparent in the continuously cropped plot and in rotation 28, where the companion crop is oats, particularly for the last two periods. The largest yield obtained, 44.1 bushels per acre, was harvested from rotation 48 in 1925. As with oats, the natural productivity of the soil is apparent when the yields of the first few years are considered.

TABLE 5.—*Acre yields of spring wheat (bushels) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
3	17.7	23.1	42.0	26.3	9.8	33.4	22.7	18.9	8.7	8.9	18.5
18	23.7	31.3	28.6	25.3	16.1	32.9	35.3	21.1	15.0	15.7	24.7
28	19.9	13.7	22.1	12.1	6.3	16.8	17.0	7.7	7.7	9.1	18.0
48	34.7	20.6	37.0	30.4	11.1	36.9	44.1	24.9	13.0	20.0	30.9
Annual mean	24.0	22.2	32.4	23.5	10.8	30.0	29.8	18.2	11.1	13.4	23.0
Maximum	34.7	31.3	42.0	30.4	16.1	36.9	44.1	24.9	15.0	20.0	30.9
Range	17.0	17.6	19.9	18.3	9.8	20.1	27.1	17.2	7.3	11.1	12.9

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean, 1918–1923	Mean, 1924–1929
3	5.9	5.8	3.7	4.7	11.0	8.2	4.0	25.4	13.9	6.2
18	13.5	20.0	25.3	24.3	20.0	28.7	24.1	26.3	20.9	23.7
28	5.7	4.2	4.6	4.1	13.7	8.4	6.1	15.2	10.9	6.9
48	18.1	16.6	43.5	27.7	19.3	18.7	17.9	28.5	25.2	24.0
Annual mean	10.8	11.7	19.3	15.2	16.0	16.0	13.0	23.9	17.7	15.2
Maximum	18.1	20.0	43.5	27.7	20.0	28.7	24.1	-------	-------	-------
Range	12.4	15.8	39.8	23.6	9.0	20.5	20.1	-------	-------	-------

Winter wheat was grown in only one rotation—No. 66—the yields from which are compared with the continuously cropped plot, rotation 6. (Table 6.) Under ordinary conditions winter wheat does not fit advantageously into the planting program of most irrigated farms in the Belle Fourche area, consequently this crop has not been featured in these investigations. Winterkilling has been an important limiting factor in obtaining good yields, with the result that the acre production is rarely high and often quite low and an occasional crop failure occurs.

TABLE 6.—*Acre yields of winter wheat (bushels) from the irrigated rotations, Belle Fourche Field Station, 1913–1929*

Rotation No.	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
5	15.3	37.0	44.3	14.3	23.3	23.6	14.7	4.0	14.0	15.0
66	15.0	16.4	15.8	13.9	23.4	26.5	7.3	3.1	6.7	-------
Annual mean	15.2	26.7	30.1	14.1	23.4	25.1	11.0	3.6	10.4	7.5

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1913–1917	Mean, 1918–1923	Mean, 1924–1929
5	8.7	13.8	5.1	9.9	4.4	6.1	12.9	26.8	13.3	8.7
66	16.7	23.1	18.7	11.9	7.3	11.6	17.3	16.9	10.1	15.0
Annual mean	12.7	18.5	11.9	10.9	5.9	8.9	15.1	21.9	11.7	11.9

The highest yields recorded are those from the early years, which is consistent with the results secured with oats and spring wheat. The relatively poor showing made by rotation 66 is attributed to accidental injuries rather than to the low productivity of the soil. This is evident from the yields given for the years 1919 to 1922 and again in 1927 and 1928.

FLAX

Flax was included in these investigations in two rotations and one plot continuously cropped. The crop is not extensively grown on the Belle Fourche project, but it is of some importance under dryland conditions elsewhere in the northern Great Plains. Information was sought as to the extent to which the yields obtained from long-continued records would justify incorporating the crop in a farming program under irrigation, and the results are given in Table 7.

TABLE 7.—*Acre yields of flax (bushels) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
9	12.3	10.5	20.7	16.9	8.0	17.6	13.9	3.9	-------	10.8	8.9
65	15.7	15.5	21.4	18.7	8.1	17.5	24.0	9.2	16.8	19.5	17.6
66	17.3	18.6	15.7	16.4	8.4	16.6	24.1	12.8	15.3	12.1	14.4
Annual mean	15.1	14.9	19.3	17.3	8.2	17.2	20.7	8.6	10.7	14.1	13.6
Maximum	17.3	18.6	21.4	18.7	8.4	17.6	24.1	12.8	16.8	19.5	17.6
Range	5.0	8.1	5.7	2.3	.4	1.0	10.2	8.9	16.8	8.7	8.7

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean, 1918–1923	Mean, 1924–1929
9	10.0	6.5	8.6	10.5	9.9	11.4	7.9	14.3	7.9	9.1
65	17.1	10.0	3.2	15.9	18.8	13.6	16.0	16.2	17.4	12.9
66	13.9	13.2	10.8	16.0	18.1	18.4	12.0	15.5	15.4	14.8
Annual mean	13.7	9.9	7.5	14.1	15.6	14.5	12.0	15.3	13.6	12.3
Maximum	17.1	13.2	10.8	16.0	18.8	18.4	16.0	-------	-------	-------
Range	7.1	6.7	7.6	5.5	8.9	7.0	8.1	-------	-------	-------

The largest yield, 24.1 bushels per acre, was harvested from rotation 66 in 1918. The yields have been erratic. The low yields in 1919 and 1925 were largely attributed to the wilt disease. For the last 12 years the yields from the continuously cropped plot, rotation 9, have been consistently low. It has been evident that this was due as much to weed competition as to declining productivity of the soil.

BARLEY

Since the advent of the sugar-beet industry in the Belle Fourche area, barley has developed into a crop of considerable importance. It has proved to be a very satisfactory grain crop following sugar beets and an excellent nurse crop for alfalfa. The three rotations in which barley was included in the planting program afford an opportunity of ascertaining yields to be expected in well-planned rotations similar to Nos. 37 and 66 and comparable with plot 10, which is continuously cropped. The results are tabulated in Table 8.

TABLE 8.—*Acre yields of barley (bushels) from the irrigated rotations, Belle Fourche Field Station, 1912–1929*

Rotation No.	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
10	-------	-------	22.6	39.0	12.5	18.3	16.8	10.8	7.3	10.3	10.0
37	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
66	28.0	14.8	31.7	63.3	36.3	38.5	26.8	18.0	28.1	19.3	32.5
Average	28.0	14.8	27.2	51.2	24.4	28.4	21.8	14.4	17.7	14.8	21.3

Rotation No.	1923	1924	1925	1926	1927	1928	1929	Mean, 1912–1917	Mean, 1918–1923	Mean, 1924–1929
10	6.8	18.4	19.4	17.5	7.7	19.7	15.8	[1] 23.1	10.3	16.4
37	38.5	46.5	58.8	35.7	36.8	50.6	48.7	-------	-------	46.2
66	21.7	27.3	29.3	28.4	28.8	28.3	40.8	35.4	24.4	30.5
Average	22.3	30.7	35.8	27.2	24.4	32.9	35.1	29.3	17.4	31.0

[1] 4-year mean yield, 1914–1917.

The yields from plot 10, continuously cropped to barley, have been low throughout the period of observation. As has been the case with the other cereals, weed competition has been an important limiting factor when such crops are not grown in a rotation with intertilled crops. The highest yield harvested, 63.3 bushels per acre, was from rotation 66 in 1915; and the lowest, 6.8 bushels per acre, was from rotation 10 in 1923. Three-year rotation 37 includes sweetclover, which is pastured; it has returned very satisfactory barley yields each year, having the highest mean for the last six years.

ALFALFA

Alfalfa was incorporated in these experiments primarily for the purpose of observing its residual effect on succeeding crop yields when grown two or three successive years in a number of rotations as compared with similar rotations not including alfalfa. The value of alfalfa as a substitute for manure also may be observed. The yields of alfalfa are given in Table 9. In tabulating the results it has seemed desirable to record the yields separately, according to the age of the crop. As an illustration, 40–1 indicates the yield from that rotation the first year of alfalfa, 40–2 indicates the yield the second year of alfalfa, and 60–3 implies the third year of alfalfa from rotation 60. Thus from Table 9 the average yield to be expected from alfalfa the first year after seeding may be observed, as well as the yields that have been obtained the second and third years.

TABLE 9.—*Acre yields of alfalfa (tons) from the irrigated rotations, Belle Fourche Field Station, 1913–1929*

Rotation No.	1913	1914	1915	1916	1917	1918	1919	1920	1921
8-a[1]	3.23	5.16	3.84	4.70	3.79	4.22	3.71	3.88	4.43
8-b[1]	5.47	4.67	4.08	4.40	3.91	4.51	5.84	5.22	5.60
40-1	.83	2.48	1.01	1.37	.74	1.96	.99	.71	.86
40-2	3.04	3.08	3.38	3.72	3.00	3.70	3.17	3.20	3.08
42-1	1.02	1.56	1.06	1.17	.67	1.64	1.20	.78	.44
42-2	2.87	3.34	4.08	3.65	2.16	3.32	2.39	3.25	3.49
44-1	2.15	2.24	3.00	2.60	2.83	2.67	3.05	1.76	2.74
44-2	4.58	4.29	3.60	4.36	4.22	4.02	4.59	4.14	4.00
46-1					1.31	2.17	2.25	.95	1.26
46-2					[2] 1.25	3.24	2.94	2.97	1.94
48-1	2.31	2.28	4.80	4.42	3.72	2.70	3.14	2.24	3.24
48-2	5.37	5.14	4.37	5.20	4.54	4.79	4.86	3.70	4.47
60-1	.76	1.84	1.17	1.84	1.18	1.79	1.30	.68	.46
60-2	2.90	2.98	3.90	3.89	3.78	4.44	3.79	3.35	3.21
60-3	[3] 3.11	3.32	3.34	3.57	2.07	4.26	4.88	4.20	4.16
61-1	1.33	1.66	1.03	2.08	1.51	1.77	1.20	.84	.49
61-2	3.28	3.62	4.03	4.76	4.06	4.08	4.78	3.38	3.84
61-3	[3] 3.58	3.72	3.56	4.27	4.27	3.88	4.98	3.98	4.04
62-1	.88	1.61	1.16	1.56	1.11	1.43	1.18	.70	.50
62-2	3.35	3.28	4.22	4.02	3.63	3.64	3.09	2.85	2.60
62-3	[3] 3.04	3.86	3.80	4.30	3.45	4.22	4.20	3.35	3.09
64-1					2.41	1.85	2.60	.88	2.01
64-2					[2] 2.51	3.54	2.65	3.48	4.08
64-3					[2] 2.35	[3] 3.01	3.63	3.28	4.08
65-1	1.21	1.77	3.08	2.42	2.43	2.42	3.12	1.00	2.90
65-2	3.98	4.08	3.52	3.84	3.56	3.70	3.99	3.58	3.69
69-1			3.82	3.21	1.59	1.53	3.10	1.26	3.95
69-2			[2] 3.26	3.95	2.87	3.33	2.56	3.76	4.44
71-1				3.46	2.71	2.89	3.56	1.80	1.43
71-2				[2] 3.41	2.95	3.60	4.20	4.02	4.58
First year	1.31	1.93	2.34	2.50	1.89	2.07	2.22	1.13	1.69
Second year	3.68	3.73	3.89	4.15	3.48	3.72	3.58	3.47	3.62
Third year		4.15	3.72	4.25	3.50	4.22	4.54	3.99	4.23

Rotation No.	1922	1923	1924	1925	1926	1927	1928	1929	Mean
8-a[1]	4.12	3.24	2.84	3.64	3.97	2.87	3.32	3.33	3.78
8-b[1]	5.46	4.86	4.82	6.14	5.90	3.74	5.88	5.92	5.08
40-1	2.22	1.22	1.32	1.66	1.58	.69	1.41	1.46	1.32
40-2	3.18	2.84	3.38	4.40	4.44	2.88	3.50	4.16	3.42
42-1	1.82	1.28	1.10	2.20	1.50	1.00	1.34	1.36	1.24
42-2	4.02	2.68	3.42	4.26	4.36	2.47	3.99	4.01	3.40
44-1	1.68	.80	1.66	2.52	3.57	.38	3.08	2.79	2.32
44-2	4.74	3.24	2.42	4.32	4.96	3.00	3.51	4.34	4.02
46-1	1.34	.70	1.00	2.46	2.43	.36	2.40	2.00	1.59
46-2	1.70	2.68	2.48	3.14	3.69	2.23	2.48	3.02	2.60
48-1	1.76	.98	.98	4.06	4.41	.53	3.48	4.12	2.89
48-2	4.76	3.54	2.57	5.06	5.99	3.49	3.37	4.87	4.48
60-1	1.70	.98	1.00	1.76	1.33	.86	.94	1.16	1.22
60-2	4.12	2.96	2.88	4.94	4.69	2.42	3.56	4.03	3.64
60-3	4.28	3.58	4.06	5.20	5.26	3.47	3.73	4.87	3.96
61-1	2.26	1.04	1.44	1.38	1.51	.25	2.18	1.75	1.40
61-2	3.32	3.52	3.44	4.42	4.46	2.33	3.86	4.80	3.88
61-3	2.82	3.36	4.62	5.24	4.86	3.01	3.58	4.42	4.01
62-1	1.02	.38	.86	1.20	1.42	.62	.95	1.34	1.05
62-2	3.28	1.88	2.62	3.74	4.22	2.36	3.68	3.61	3.30
32-3	3.58	3.52	2.98	5.06	4.69	3.19	4.15	4.95	3.85
64-1	1.76	1.02	1.36	3.30	4.65	1.00	2.57	3.28	2.21
64-2	4.38	2.80	2.72	5.04	5.09	3.20	2.80	4.31	3.58
64-3	4.94	3.16	2.68	4.98	5.07	3.27	4.32	3.95	3.75
65-1	1.66	.78	.98	2.50	3.81	.58	3.15	2.77	2.15
65-2	3.64	3.06	1.84	4.04	3.69	2.73	3.10	3.49	3.50
69-1	1.16	1.04	1.24	3.04	4.84	.90	3.43	2.88	2.47
69-2	4.90	2.40	3.82	4.12	5.80	3.09	3.79	4.28	3.76
71-1	1.14	1.08	1.10	2.56	4.57	.72	2.51	2.87	2.31
71-2	3.92	1.64	2.50	5.20	5.66	3.12	3.70	2.76	3.66
First year	1.63	.94	1.17	2.39	2.97	.66	2.29	2.32	1.85
Second year	3.83	2.77	2.84	4.39	4.75	2.78	3.45	3.97	3.65
Third year	4.20	3.62	3.67	5.04	4.96	3.26	4.16	4.57	4.13

[1] See text, page 19. [2] Included in first-year mean. [3] Included in second-year mean.

No yields were recorded for 1912. The alfalfa that year was seeded in the spring and clipped with a mower and left on the ground. In 1913 both the second and third year yields were combined to obtain the second-year annual mean for that season. Plots 8–a and 8–b are continuously cropped to alfalfa, and in 1913 these plots were included in arriving at the 2-year annual means. In 1914 and thereafter the yields from these two continuously cropped plots are included in arriving at the third-year annual means. This procedure has been followed throughout the 17-year period. The method of seeding has been as follows: For the first few years when following grain good stands of alfalfa were obtained by fall planting after the grain crop was removed. Since 1920 grasshoppers have been present every season and often in such numbers that frequently the fall-seeded stands have been largely destroyed, necessitating replanting the following spring. Since grasshoppers have become a serious menace, alfalfa following grain has been spring seeded, using grain as a nurse crop. When this procedure has been followed satisfactory stands have resulted, and it has been generally adopted when the planting plan permits.

The cropping system returning the highest per-acre yield is 8–b, which has received an annual application of stable manure beginning with 1916. This plot has averaged to produce since that date 1.58 tons per acre more than 8–a, which is continuously cropped but not manured. The lowest mean yield for all rotations for the 17 years is from the first year after planting, as is to be expected. The second-year mean is next, and the highest is from the third-year period. The mean yield of alfalfa the third year after planting has proved to be in excess of plot 8–a left continuously in the crop. It has been evident that after land has been in alfalfa for a long period the yields tend to diminish. This is evidenced when the yields from plot 8–a are divided into two periods. The average yield for the first nine years from this plot is 4.11 tons per acre, whereas for the next eight years the production dropped to 3.42 tons per acre.

ANNUAL FLUCTUATION IN YIELDS

The foregoing tables, giving the crop yields in detail of oats, sugar beets, potatoes, corn, spring wheat, winter wheat, flax, barley, and alfalfa, have shown that the variations in the seasonal climatic conditions have had a profound effect on crop yields. This condition has been notably evident with potatoes and sugar beets, the latter being the chief cash crop at present grown on the project. During the 18 years seasons have occurred when the weather has been so unfavorable that the benefits normally to be expected from the better cropping programs have not been realized.

Crop injury due to insect pests and plant diseases has at times been a factor of importance also. For the purpose of ascertaining and comparing the annual fluctuations in the yields of oats, sugar beets, potatoes, spring wheat, and corn, Table 10 has been compiled. The mean annual yield for each crop is expressed as a percentage of the mean annual yield for all plots in each rotation for 18 years.

TABLE 10.—*Seasonal acre yields of each crop except winter wheat, flax, and alfalfa in the irrigated rotations, expressed as percentages of the mean yields of all plots in each of such rotations, at the Belle Fourche Field Station, 1912–1929*

Crop	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
Oats	93	70	145	167	98	106	131	75	48	74	90
Sugar beets	73	74	107	90	68	122	101	------	76	100	130
Potatoes	37	89	83	92	118	114	133	49	------	124	124
Spring wheat	127	117	171	124	57	159	158	96	59	71	122
Corn	75	93	113	85	111	121	109	99	87	110	105
Mean	81	89	124	112	90	124	126	80	68	96	114

Crop	1923	1924	1925	1926	1927	1928	1929	Mean		
								1912–1917	1918–1923	1924–1929
Oats	98	102	108	101	49	128	117	113	86	101
Sugar beets	126	100	132	112	72	109	102	89	107	105
Potatoes	83	146	161	121	52	136	38	89	102	109
Spring wheat	57	62	102	80	85	85	69	126	94	80
Corn	122	77	110	113	71	115	84	101	105	95
Mean	97	97	123	105	66	115	82	103	99	98

It is apparent that there has been a wide fluctuation in the means for all crops, ranging from a maximum of 126 per cent in 1918 to a minimum of 66 per cent in 1927. There were two seasons when the mean for all crops was below 70 per cent—1927 with 66 and 1920 with 68. In both of these years the low records were due to a cold late spring combined with abnormally heavy precipitation extending well into the summer months, which materially retarded crop growth. The crop showing the greatest yield range is potatoes, extending from a minimum of 37 in 1912 to a maximum percentage of 161 in 1925, with an extreme range of 124 per cent. Corn has shown the lowest maximum range of 51 per cent; beets come next with 64 per cent, spring wheat 114 per cent, with oats next to potatoes with a range of 119 per cent. Relatively good yields from all crops were harvested in 1918 and again in 1925, when the yields recorded for all were above normal.

For the purpose of ascertaining the trends of crop yields when untreated rotations are compared with those where stable manure is applied or alfalfa included, Table 11 is presented. As in Table 10, the mean acre yield of each crop is expressed as a percentage of the mean annual yield of such crop in all rotations. The three crops used in making this comparison are oats, sugar beets, and potatoes.

TABLE 11.—*Mean annual acre yield of oats, sugar beets, and potatoes in untreated, manured, and alfalfa rotations at the Belle Fourche Field Station, 1912–1929*

[The mean acre yield of each crop is expressed as a percentage of the mean annual yield of such crop in all rotations]

Crop	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
Oats:											
Untreated	88	100	88	88	93	92	89	96	109	107	92
Manured	101	107	87	109	101	124	116	121	154	124	127
Alfalfa	109	94	113	106	106	95	101	89	75	88	98
Sugar beets:											
Untreated	99	106	94	94	90	87	88	------	88	106	91
Manured	91	113	117	146	141	141	122	------	130	139	135
Alfalfa	105	97	104	99	97	99	107	------	94	89	102
Potatoes:											
Untreated	88	94	88	81	102	93	103	115	------	87	88
Manured	107	92	110	139	113	119	122	106	------	132	137
Alfalfa	121	109	102	96	85	89	97	98	------	93	98

Crop	1923	1924	1925	1926	1927	1928	1929	Mean		
								1912–1917	1918–1923	1924–1929
Oats:										
Untreated	88	87	78	85	101	78	76	92	97	84
Manured	119	116	103	111	133	113	102	105	127	113
Alfalfa	101	103	115	109	86	111	121	104	92	108
Sugar beets:										
Untreated	90	92	89	85	89	81	84	95	[1] 93	87
Manured	136	140	133	147	137	136	147	125	[1] 132	140
Alfalfa	102	98	103	97	103	112	110	100	[1] 99	104
Potatoes:										
Untreated	86	91	89	97	70	83	97	91	[2] 96	88
Manured	122	127	119	121	128	116	121	113	[2] 124	122
Alfalfa	108	95	101	105	111	109	104	100	[2] 99	104

[1] Exclusive of the 1919 yield.

[2] Exclusive of the 1920 yield.

In only 4 years out of the 18 has the yield of oats from the untreated rotations equaled or exceeded the mean for all rotations. When the first 6-year average is compared with the last 6-year period, a yield decline of 8 per cent is indicated. The percentages show that the yield of oats in the manured rotations has been less than the mean of all rotations in only one year, 1914. When the yields from the last 6-year period of the untreated rotations are compared with those manured, it is found that the difference in favor of the manured rotations is 29 per cent. The yields of oats from the rotations including alfalfa have averaged materially higher than those from the untreated rotations, but the increase is not so pronounced as when the manurial treatment was included in the cropping program. Oats from the alfalfa rotation 11 years out of the 18 showed percentages in excess of the mean for all plots. It will be observed that the highest mean for the three crops occurred during the 1918 to 1923 period of the manured rotations and is materially higher than the first 6-year or the last period, indicating that the full benefits of manure may be expected between the seventh and twelfth years. Thereafter applications as frequent as have occurred in these series of rotations may be expected to depress yields somewhat, apparently owing to excessive vegetative growth at the expense of grain.

In the untreated rotations the sugar-beet yields have shown definite tendencies to decline on the untreated rotations the longer they are continued. There are only 2 years out of the 18 when the percentages

given are above the mean for all plots. When the results are summarized into 6-year periods the decline in yield is consistent. Where the results from the manured rotations are summarized it is found that in only one year, 1912, was the percentage of yield less than the mean for all rotations, and that was the year the rotations were begun. The benefits in the form of increased yields from the applications of manure are more striking and the results more consistent with sugar beets than with either oats or potatoes. For the last 6-year period, 1924–1929, the difference in favor of the manured rotations over those untreated is 53 per cent. The yields of sugar beets in the alfalfa rotations have only been maintained, as is evident when the percentages in the three 6-year periods are compared. However, when the last 6-year period of the alfalfa rotations is compared with the same period of the untreated rotations, there is found to be a difference of 17 per cent in favor of those in which alfalfa is included. Furthermore, these percentages do not do full justice to the value of alfalfa as a soil-improvement crop, for in one instance sugar beets immediately follow alfalfa, a practice that usually results in very low production. When a well-planned cropping program has been followed, the yields from sugar beets in alfalfa rotations often compare favorably with those receiving frequent applications of stable manure, and particularly if the last year of alfalfa is harvested by livestock.

In only 3 years out of 17 have acre yields of potatoes been equal to or above the mean annual yield on all plots on the untreated rotations, and these 3 years occurred during the first 8. The advantages to be expected in the form of increased yields is clearly indicated in the percentages given for the rotations receiving applications of stable manure. The effect of this treatment as compared with the rotations may be compared by taking the differences in percentages for the three 6-year periods. These differences are as follows: 1912 to 1927, 22 per cent; 1918 to 1923, 28 per cent; and 1924 to 1929, 34 per cent—all in favor of the rotations receiving the manurial treatment. As with sugar beets, alfalfa included in the cropping system has not resulted in materially stimulating the yields of potatoes when all such rotations are included in the average. The effect of alfalfa on the yield of potatoes may be observed by determining the difference in percentages in the three 6-year periods between the alfalfa rotations and those untreated. These differences are as follows: 1912 to 1917, 9 per cent; 1918 to 1923, 3 per cent; and 1924 to 1929, 16 per cent.

Over an 18-year period Table 11 indicates the extent to which the yields of oats, sugar beets, and potatoes may be expected to decline in untreated rotations. The value of stable manure as a means of increasing crop yields is clearly evident. On the average alfalfa has not stimulated crop yields appreciably, but they have been maintained.

EFFECT OF THE ROTATIONS ON CROP YIELDS SUMMARIZED AND COMPARED

In the foregoing pages and in Tables 1 to 9 the effect on crop yields of the various rotations has been given in detail. In order to permit comparison of the results obtained, these are summarized for the different crops in 6-year periods in Tables 12 to 19. One table is devoted to each crop, and in addition to affording an opportunity of

comparing one rotation with another, the rotations are grouped in such a manner that the yields from all 2-year untreated rotations may be compared with those on plots continuously cropped as well as from the 3-year untreated rotations. The effect of manure may be observed in both 2-year and 3-year rotations when compared with those not so treated. The effect on crop yields of alfalfa grown for two years may be compared with similar rotations but when the crop is grown for three years. Alfalfa rotations 61, 65, 69, and 71, which include either certain pasturing practices or an application of manure, may be compared with similar rotations where the practice has been to harvest the crop for hay or manure is not applied.

In comparing the results obtained from these rotation experiments in the following tables the data have been so arranged that the yields for the first, second, and third 6-year periods may be compared. This arrangement permits observations to be made as to the trend of yields. In the last three columns of each table are given the increase or decrease for each rotation for each 6-year period as compared with the annual mean for all rotations in which the different crops appear, together with the probable error, computed for the purpose of determining the degree of dependability of the differences in yields. The method of computing the probable error here used is to multiply the sum of the departures from the mean by the quotient of $M\sqrt{N-1}$ into 0.8453 where N equals the number of yields involved.[2]

The practical application of the value of determining the probable error may be illustrated in Table 12, giving the yield of oats, using continuously cropped rotation No. 1. For the first 6-year period the average yield of this plot is 1.8 bushels in excess of the mean yields of all rotations, and the probable error is ±4.62 bushels. The difference in yield is small, and the probable error is large, indicating that for the first 6 years no ill effects were apparent from growing oats on the same land continuously. For the next 6-year period, 1918 to 1923, the difference in yield is −11.4 bushels with a probable error of ±4.00. Were yields only considered, this difference would be definitely significant but with a probable error of slightly less than three times the difference, a wide fluctuation in yields for the period is indicated. On the other hand, for the last six years, 1924 to 1929, the difference in yield is −18.2 bushels per acre with a probable error of only ±3.66 bushels, a difference that is definitely significant and emphasizing the adverse effect on the yield of oats likely to be encountered when the crop is grown continuously on the same land for a long period.

The results of these investigations contribute additional evidence that a system of crop rotation or special treatment of the soil is essential to the continued productivity of irrigated lands. Further, it appears that while satisfactory yields may be obtained for some years if only crop rotation is practiced and no special treatment is included in the cropping program, yet eventually yields will decline unless there is an occasional application of stable manure or unless such a soil-improvement crop as alfalfa or sweetclover is included. It has been apparent that most immediate results in connection with the improvement in yields will be realized from applications of stable manure. However, owing to the present limited

[2] MERRIMAN, M. A TEXTBOOK OF THE METHOD OF LEAST SQUARES. Ed. 8, New York, 1913.

number of livestock on the Belle Fourche project, only a small part of the quantity required to meet the farmer's needs adequately is usually available. This condition was recognized at the time these experiments were begun, and alfalfa was included largely for the purpose of determining how effectively it could be utilized in the cropping system as a substitute for manure. Later sweetclover was added, partly because of its more rapid growth the first season and also because of the fact that when it is pastured the danger of bloating is less than with alfalfa. In certain rotations observations have been made to ascertain how profitable the procedure may prove to be when corn, alfalfa, and sweetclover are harvested with livestock as compared with the more common practices of removing these crops in the customary manner. It was believed that determining the effect on succeeding crop yields when this practice was followed might result in assembling further information on how crop yields could be economically stimulated aside from the applications of stable manure.

In the following tables the benefits in the form of increased yields due to improved cropping systems are clearly apparent. However, there are other important advantages not always reflected in crop yields. Growing the same crop on the same land even for a few years not infrequently results in excessive weed growth, intensifies the damage by plant diseases and insect pests, or increases the expense of their control. There are still further advantages resulting from crop rotation. When such a practice is followed, two or more crops are necessarily included in the cropping program, resulting in diversification of the farmer's activities. It is generally accepted as a fact in areas devoted to the production of the more common farm crops that farmers who diversify are able to utilize their time and equipment more effectively than if they are largely or wholly confining their operations to one crop. When farmers are not dependent solely upon an income from a single crop, as a rule their business is on a more stable basis and a financial loss resulting from low yields or depressed prices on a particular crop does not necessarily indicate that they will sustain losses on their combined operations for the season. It is obvious that all the advantages of a well-planned rotation are not reflected in the foregoing and following tables, but such factors should be taken into consideration when the comparative merits of the different cropping systems are being considered.

In making comparisons of the differences in yields obtained from the various crop sequences and treatments applied in these rotations, which are summarized in the tables to follow, it is recognized that but little emphasis should be placed upon the results for the first 6-year period, 1912 to 1917. Some crops produce relatively satisfactory yields for a few years after breaking up the native sod. Apparently this condition obtained in the case of wheat, oats, and barley at the Belle Fourche Field Station, as is quite generally evidenced by the yields harvested from these crops during the earlier years of the experiments. On the other hand, when the yields of sugar beets are considered, the results indicate that even when the crop is grown continuously on the same land, yields the first five or six years are likely to be less than may be expected for an equal period immediately following. The average yield from sugar beets from the continuously cropped plot for the period of 1912 to 1917 was 6.5 tons per acre, whereas the yield the next six years was

8.3 tons per acre. The effect of the various crop sequences on crop yields, and the results from the inclusion of alfalfa in the rotations as compared with those where this crop is not included were not strikingly apparent until well into the second 6-year period. However, the yields recorded for the years 1912 to 1917 serve a useful purpose in giving information as to the relative productiveness of the different plots and in ascertaining to what extent crop yields are being maintained. Consequently, in the text accompanying the following tables these facts have been taken into consideration.

OATS

In Table 12 are given the average annual yields of oats from 1912 to 1929 divided into three 6-year periods. The rotations are grouped and the yields averaged for the different groups as follows: Continuously cropped; 2-year rotations, untreated; 2-year rotations, manured; 3-year rotations, untreated; 3-year rotations, manured; 4-year alfalfa rotations; 6-year alfalfa rotations, untreated; and 6-year alfalfa rotations, manured or pastured. This grouping permits a comparison of the different treatments of oats without regard to crop sequences. For the purpose of ascertaining to what extent different crop sequences influence yields, comparisons are made between pairs of rotations.

TABLE 12.—*Average annual yields of oats from various rotations compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa, and pasturing, at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of oats (bushels), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping:							
No. 1	Oats	66.8	37.8	39.5	+1.8±4.62	−11.4±4.00	−18.2±3.66
2-year rotations, untreated:							
No. 16	Oats, corn	55.2	41.4	46.6	−9.8±3.71	−7.8±2.69	−11.1±2.94
No. 22	Oats, sugar beets	68.0	54.6	59.0	+3.0±1.37	+5.4±1.35	+1.3± .88
No. 24	Oats, potatoes	68.2	63.0	59.0	+3.2±2.84	+13.8±1.63	+1.3±1.85
No. 27	Oats (winter rye), potatoes	66.6	61.2	59.9	+1.6±2.77	+12.0±1.07	+2.2±2.22
No. 28	Oats, spring wheat	35.2	26.7	17.0	−29.8±5.44	−22.5±3.67	−40.7±4.52
Average		58.6	49.4	48.3			
2-year rotations, manured:							
No. 23	Oats (manure), sugar beets	66.5	59.4	63.0	+1.5±3.04	+10.2±1.48	+5.3±1.52
No. 25	Oats (manure), potatoes	60.1	66.3	73.8	−4.9±4.42	+17.1±1.03	+16.1±2.17
Average		63.3	62.9	68.4			
3-year rotations, untreated:							
No. 30	Oats, sugar beets, potatoes	68.3	51.1	58.2	+3.3±2.51	+1.9±3.02	+.5±2.36
No. 32	Oats, corn, sugar beets	57.1	36.0	41.8	−7.9±3.85	−13.2±3.12	−15.9±2.99
No. 34	Oats, potatoes, sugar beets	-------	54.0	50.6	-------	+4.8±2.18	−7.1±5.27
Average		62.7	47.0	50.2			
3-year rotations, manured:							
No. 31	Oats (manure), sugar beets, potatoes	76.3	61.5	68.7	+11.3±1.05	+12.3±1.65	+11.0±1.52
No. 35	Oats (manure), potatoes, sugar beets	-------	56.5	50.8	-------	+7.3±1.42	−6.9±3.03
Average		76.3	59.0	59.8			

4-year alfalfa rotations:							
No. 42	Oats, sugar beets, alfalfa (2 years)	47.9	36.6	46.7	−17.1±3.47	−12.6±3.53	−11.0±3.06
No. 44	Oats, alfalfa (2 years), potatoes	82.2	45.7	75.3	+17.2±2.46	−3.5±5.25	+17.6±2.91
No. 46	Oats, alfalfa (2 years), sugar beets		38.6	64.6		−10.6±3.01	+6.9±4.77
No. 48	Oats, alfalfa (2 years), spring wheat	80.9	47.9	67.3	+15.9±2.97	−1.3±3.72	+9.6±3.47
Average		70.3	42.2	63.5			
6-year alfalfa rotations, untreated:							
No. 60	Oats, sugar beets, alfalfa (3 years), potatoes	65.0	49.8	68.4	+0 ±3.06	+.6±1.87	+10.7±3.66
No. 62	Oats, sugar beets, alfalfa (3 years), corn	61.1	37.6	53.0	−3.9±4.45	−11.6±2.39	−4.7±1.88
No. 64	Oats, alfalfa (3 years), potatoes, sugar beets		50.4	54.4		+1.2±3.07	−3.3±1.35
Average		63.1	45.9	58.6			
6-year alfalfa rotations, manured or pastured:							
No. 61	Oats (manure), sugar beets, alfalfa (3 years), potatoes	73.3	48.7	71.2	+8.3±4.67	−.5±1.45	+13.5±3.18
No. 65	Oats, alfalfa (3 years, pastured third year), corn (pastured), flax	72.0	45.4	59.8	+7.0±3.86	−3.8±3.40	+2.1±3.24
No. 69	Oats, alfalfa (3 years, pastured third year), corn (pastured), corn (pastured).		55.4	71.2		+6.2±2.37	+13.5±4.80
No. 71	Oats, alfalfa (3 years, pastured third year), corn (pastured), sugar beets.		54.4	66.1		+5.2±3.39	+8.4±4.79
Average		72.7	51.0	67.1			

The lowest yields recorded for oats in Table 12 for the last two periods are from the plot continuously cropped, and the next higher is from the 2-year untreated rotations, with the 3-year untreated rotations following. The highest yields for the last 6-year period are from the 6-year alfalfa rotations either manured or pastured and from the 2-year rotations receiving an application of stable manure every second season. For the same period the 3-year rotations having an application of manure every third year and the 4-year and 6-year untreated alfalfa rotations are close together. The original productivity of the land where these experiments are located is clearly evident when the average yield for 1912 to 1917 is compared with that for the last 6-year period. In only one instance is the latter yield higher, and that is for the 2-year manured rotations.

Oats in a 2-year rotation with spring wheat, No. 28, have produced lower yields than when the crop has been grown continuously on the same land. Also in 2-year rotation 16, where corn is the companion crop, the yields are definitely less than the mean for all rotations. These results further indicate that even in rotation 65, where oats follow flax, the results are not as good as where oats follow a cultivated crop.

As a rule, better yields have been obtained in these rotations for the last six years when oats follow potatoes rather than sugar beets. This is apparent when rotations 23 and 25, 32 and 34, 31 and 35, as well as 44 and 46, are compared. The only exception is found in the yields from 2-year untreated rotations 22 and 24. Oat yields following alfalfa in rotation 42 have been consistently lower for the three periods than those of any of the other rotations that have included alfalfa.

SUGAR BEETS

When the different treatments are grouped and compared in Table 13, tabulating the yields of sugar beets, the lowest yields for the last two periods are from 6-year rotation 66, which includes one year of red clover seeded in with winter wheat in the fall. The reason for such poor yields from this rotation has not been clear, but it appears that sugar beets following red clover is not a good sequence. Low yields for all three periods are shown for the continuously cropped plot 2, and for the last period this plot is the lowest of any except rotation 66. The increases in yields of sugar beets resulting from an application of manure every other year as compared with every third year are evident when the average of the 2-year manured rotations is compared with the average of the 3-year manured rotations. Six-year alfalfa rotations where the crop is left in for three years have resulted in larger yields of sugar beets than 4-year rotations with only two years of alfalfa.

TABLE 13.—*Average annual yields of sugar beets from various rotations compared with the annual means, showing the effect of continuous cropping, simple rotations, manure, alfalfa, and pasturing, at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of sugar beets (tons), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping:							
No. 2	Sugar beets	6.5	8.3	5.9	−2.8±0.53	−2.9±0.76	−5.1±0.54
2-year rotations, untreated:							
No. 18	Sugar beets, spring wheat	8.5	7.9	7.4	− .8± .21	−3.3± .32	−3.6± .26
No. 20	Sugar beets, potatoes	11.0	13.1	12.7	+1.7± .50	+1.9± .61	+1.7± .45
No. 22	Sugar beets, oats	9.6	11.4	11.4	+ .3± .21	+ .2± .47	+ .4± .47
Average		9.7	10.8	10.5			
2-year rotations, manured:							
No. 21	Sugar beets, potatoes (manure)	12.8	16.3	17.6	+3.5± .87	+5.1± .74	+6.6± .71
No. 23	Sugar beets, oats (manure)	11.2	15.5	15.9	+1.9± .95	+4.3± .76	+4.9± .57
Average		12.0	15.9	16.8			
3-year rotations, untreated:							
No. 30	Sugar beets, potatoes, oats	7.7	8.1	6.8	−1.6± .66	−3.1± .30	−4.2± .49
No. 32	Sugar beets, oats, corn	7.0	6.8	6.0	−2.3± .53	−4.4± .25	−5.0± .33
No. 34	Sugar beets, oats, potatoes		14.6	12.8		+3.4± .64	+1.8± .40
Average		7.4	9.8	8.5			
3-year rotations, manured:							
No. 31	Sugar beets, potatoes, oats (manure)	11.4	12.2	13.0	+2.1± .38	+1.0± .67	+2.0± .33
No. 35	Sugar beets, oats (manure), potatoes		15.4	14.8		+4.2± .39	+3.8± .50
Average		11.4	13.8	13.9			
4-year alfalfa rotations:							
No. 40	Sugar beets, alfalfa (2 years), potatoes	10.6	12.3	12.8	+1.3± .16	+1.1± .30	+1.8± .60
No. 42	Sugar beets, alfalfa (2 years), oats	8.4	9.5	9.1	− .9± .67	−1.7± .13	−1.9± .29
No. 46	Sugar beets, oats, alfalfa (2 years)		6.9	7.2		−4.3± .63	−3.8± .49
Average		9.5	9.6	9.7			

TABLE 13.—*Average annual yields of sugar beets from various rotations compared with the annual means, showing the effect of continuous cropping, simple rotations, manure, alfalfa, and pasturing, at the Belle Fourche Field Station, 1912–1929*—Continued

Rotation	Crops in the rotation	Average annual acre yields of sugar beets (tons), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
6-year alfalfa rotations, untreated:							
No. 60	Sugar beets, alfalfa (3 years), potatoes, oats	9.5	11.5	10.4	+0.2±0.08	+0.3±0.48	−0.6±0.20
No. 62	Sugar beets, alfalfa (3 years), corn, oats	8.6	9.1	9.1	−0.7± .40	−2.1± .70	−1.9± .38
No. 64	Sugar beets, oats, alfalfa (3 years), potatoes	---	12.4	12.6	---	+1.2± .25	+1.6± .66
Average		9.1	11.0	10.7			
6-year alfalfa rotations, manured or pastured:							
No. 61	Sugar beets, alfalfa (3 years), potatoes, oats (manure)	10.5	13.5	14.1	+1.2± .58	+2.3± .52	+3.1± .74
No. 71	Sugar beets, oats, alfalfa (3 years, pastured third year), corn (pastured)	---	13.5	16.0	---	+2.3±1.06	+5.0± .77
Average		10.5	13.5	15.1			
6-year red-clover rotation:							
No. 66	Sugar beets, flax, barley, corn, winter wheat, red clover	6.8	5.2	4.5	−2.5± .91	−6.0±1.16	−6.5± .65

The yields of sugar beets following oats or wheat are relatively low, as is apparent when the yields from rotations 18, 22, and 30 are compared. Even when manure is applied preceding the sugar beets in a 2-year rotation with oats, the yields of sugar beets have been materially less than when the companion crop is potatoes. Consistent differences are apparent in the yields from rotations 31 and 35, these rotations being identical as to crops and varying only in the sequence of the crops. In general the same results have been

FIGURE 3.—Comparison of sugar beets in rotations with same crops in different sequence. A, Rotation 30, with sequence of potatoes, oats, sugar beets. B, Rotation 34, with sequence of potatoes, sugar beets, oats. Note poor growth of A as compared with B. For the last 6-year period rotation 34 outyielded rotation 30 by 6 tons per acre

obtained from the untreated alfalfa rotations when the yields from rotation 40 are compared with those from rotation 42 and when the yields from rotations 60 and 62 are compared with those from rotation 64. (Fig. 3.) Yields materially less than the mean for all rotations for the last two periods have occurred from 4-year alfalfa rotation 46, where sugar beets immediately follow alfalfa. Apparently this result has been due in a large measure to the condition of the land following alfalfa. At least in part this is due to the prevalence of undecayed alfalfa roots, causing difficulties in preparing a satisfactory seed bed and later in cultivating the sugar beets.

The beneficial effect of stable manure is consistently reflected in all rotations that have been so treated. The highest yield recorded for any period, when all rotations are considered, is that obtained from rotation 21 for the last 6-year period, which averaged 17.6 tons per acre, or 4.9 tons more than rotation 20, which is similar as to

FIGURE 4.—Comparison of sugar beets in rotation with potatoes with and without manure. A, Rotation 20, unmanured. B, Rotation 21, identical with 20 as to crops, but with stable manure applied before planting the sugar beets. For the last 6-year period rotation 21 outyielded rotation 20 by 4.9 tons per acre

crops but not manured. (Fig. 4.) Rotations 30 and 31 are identical as to crops and sequence, the only difference being an application of manure every third year preceding the sugar beets. The difference in the yields when all the periods are considered has been 4.7 tons per acre in favor of the manured rotation. Even when three years of alfalfa is included in the cropping program, an application of manure has materially increased the yield of sugar beets. Rotations 60 and 61 are identical as to crops and sequence, the only difference

being an application of manure to rotation 61 preceding the sugar-beet crop every sixth year. The increase in yield by periods when rotation 60 is compared with rotation 61 has been, respectively, 1, 2, and 3.7 tons per acre. The yields from rotation 60 are scarcely being maintained, while those from rotation 61 have been progressively increasing, indicating that the full benefits of such a treatment are still to be realized.

The favorable effect on the yields of sugar beets as a result of pasturing are apparent when the yields from rotation 71 are compared with the others. The yields of sugar beets from this rotation for the period 1918 to 1923 were 2.3 tons above the mean for all rotations, and for the last period, 1924 to 1929, were 5 tons above the average for all rotations and second only to rotation 21, which has returned the highest average yields of all rotations for the period.

POTATOES

As is evident from the data recorded in Table 3, the annual yields of potatoes from the rotations throughout the 18-year period have fluctuated greatly. There have been years of relatively low yields from all rotations irrespective of the treatment. The reasons for this have already been discussed. Because these years of low yields have not always been distributed uniformly throughout the three 6-year periods, the trend of yields as recorded in Table 14 does not reflect accurately the cumulative effect of the different treatments. This is illustrated by what occurred in the last 6-year period, 1924 to 1929, when for the years 1927 and 1929 low yields were harvested, the average yield of all rotations for those two years being 68.3 and 49.4 bushels per acre respectively. The mean for these two years is 59 bushels, as compared wish a mean yield of 183.3 bushels per acre harvested in the other four years of the period. Two years with such low production not only have a marked effect on the indicated trend of yields but have been a factor in minimizing the differences between the cropping systems. In considering the summary of results obtained from potatoes as given in Table 14, the foregoing should be taken into account.

The highest yields obtained when the rotations are grouped are those from the 3-year rotations having an application of stable manure every third year. The lowest yields are those from rotation 27, a potatoes-oats sequence where rye is seeded in the oat stubble in the fall and plowed under the following spring prior to planting the potatoes. For the last 6-year period the 3-year untreated rotations have given higher yields than the average for the untreated two 2-year rotations.

TABLE 14.—*Average annual yields of potatoes from various rotations compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, manure, alfalfa, and pasturing, at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of potatoes (bushels), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping:							
No. 4	Potatoes	136.0	102.3	125.9	+20.5±3.72	−31.0±5.65	−16.1±7.90
2-year rotation, untreated:							
No. 20	Potatoes, sugar beets	112.8	107.7	90.2	−2.7±5.94	−25.6±9.36	−51.8±9.34
No. 24	Potatoes, oats	103.0	125.3	134.2	−12.5±4.81	−8.0±4.57	−7.8±8.04
No. 26	Potatoes, corn	115.6	125.3	138.3	+.1±3.20	−8.0±9.03	−3.7±5.11
Average		110.5	119.4	120.9			
2-year rotation, rye:							
No. 27	Potatoes, oats, (rye, plowed under)	97.3	76.6	96.4	−18.2±5.19	−56.7±19.54	−45.6±9.59
2-year rotations, manured:							
No. 21	Potatoes, sugar beets (manure)	143.6	181.7	151.0	+28.1±7.23	+48.4±11.58	+9.0±5.85
No. 25	Potatoes, oats (manure)	117.1	148.1	169.0	+1.6±6.85	+14.8±13.25	+27.0±7.44
Average		130.4	164.9	160.0			
3-year rotations, untreated:							
No. 30	Potatoes, oats, sugar beets	92.7	121.4	127.0	−22.8±9.20	−11.9±11.12	−15.0±4.25
No. 34	Potatoes, sugar beets, oats		147.1	138.4		+13.8±4.51	−3.6±5.44
Average		92.7	134.3	132.7			
3-year rotations, manured:							
No. 31	Potatoes, oats (manure), sugar beets	135.6	175.0	180.4	+20.1±7.77	+41.7±14.06	+38.4±5.53
No. 35	Potatoes, sugar beets, oats (manure)		169.5	189.8		+36.2±10.82	+47.8±14.42
Average		135.6	172.3	185.1			
4-year alfalfa rotations:							
No. 40	Potatoes, sugar beets, alfalfa (2 years)	101.0	155.1	137.9	−14.5±5.46	+21.8±6.23	−4.1±5.03
No. 44	Potatoes, oats, alfalfa (2 years)	137.1	146.6	183.8	+21.6±5.41	+13.3±6.88	+41.8±9.54
Average		119.1	150.9	160.9			
6-year alfalfa rotations, untreated:							
No. 60	Potatoes, oats, sugar beets, alfalfa (3 years)	103.9	128.3	144.1	−11.6±7.65	−5.0±5.82	+2.1±5.27
No. 64	Potatoes, sugar beets, oats, alfalfa (3 years)		101.1	132.3		−32.2±4.90	−9.7±9.66
Average		103.9	114.7	138.2			
6-year alfalfa rotation, manured:							
No. 61	Potatoes, oats (manure), sugar beets, alfalfa (3 years)	105.9	122.0	133.2	−9.6±6.70	−11.3±4.13	−8.8±5.26

In comparing the various rotations individually it is found that the lowest yields of potatoes for the three 6-year periods are those from the 2-year rotation 27. The low yields harvested from this rotation have appeared to be largely due to the difficulty encountered in connection with preparing a proper seed bed for the potatoes following the rye. It appears that potatoes in a 2-year rotation with sugar beets will not produce as large yields as when either oats or corn is the companion crop. That oats are a better crop than sugar beets to precede potatoes is further evidenced by comparing the yields from rotations 30 and 34.

In the majority of instances the yields of potatoes in the alfalfa rotations have been larger than those obtained from the untreated rotations, but less than from those receiving manure. However, it is noteworthy that there is a definite tendency for the potato yields of the alfalfa rotations to increase as time goes on. Yield increases of potatoes as a result of the application of stable manure in both the 2-year and 3-year rotations were immediate and appreciable when the second period is compared with the first. The yields of potatoes in the alfalfa rotations indicate a definite tendency to increase the longer the rotations are continued. An exception to this is rotation 40. This rotation is located in the southeast corner of the series, and since 1923 there have been evidences of a high-water table which may have depressed the yields. With soil conditions comparable with those existing where these experiments have been conducted, these results indicate that with potatoes the application of manure may be expected to increase yields for 10 or 12 years, after which yield increases may be less apparent. Where alfalfa is included in the cropping program, yields may be increased much less rapidly, but the full benefits of such rotations in the form of increased production apparently have not been reached in the 18-year period covered by these investigations. The yields of potatoes from manured-alfalfa rotation 61 have not been appreciably different from those harvested from rotation 60, which is identical as to crop and sequence.

CORN

A summary of the results obtained from the seven rotations where corn is included in the planting program is given in Table 15. Relatively uniform yields have been obtained, as is apparent when the results of the different cropping systems are summarized and compared by 6-year periods.

TABLE 15.—*Average annual yields of corn compared with the annual means of all rotations, showing the effect of continuous cropping, simple rotations, and alfalfa rotations at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of corn (bushels), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping:							
No. 6	Corn	45.5	42.5	34.9	+6.8±2.64	+2.3±1.82	−1.5±2.45
2-year rotations:							
No. 16	Corn, oats	37.5	36.4	30.5	−1.2±1.85	−3.8± .71	−5.9±1.16
No. 26	Corn, potatoes	35.0	41.7	31.8	−3.7±1.63	+1.5±2.35	−4.6±1.28
3-year rotation:							
No. 32	Corn, sugar beets, oats	35.3	39.5	30.2	−3.4±1.45	− .7±2.15	−6.2±1.90
3-year sweetclover rotation:							
No. 37	Corn, barley, sweetclover (pastured).	-----	-----	46.7	----------	----------	+10.3± .85
6-year alfalfa rotation:							
No. 62	Corn, oats, sugar beets, alfalfa (3 years).	37.1	38.7	41.2	−1.6± .69	−1.5±1.15	+4.8±1.92
6-year red-clover rotation:							
No. 66	Corn, winter wheat, red clover, sugar beets, flax, barley.	41.7	42.3	39.3	+3.0±2.05	+2.1±3.48	+2.9±1.76

For the first 6-year period the yield from plot 6, continuously cropped, was relatively high. The yields from this plot have indicated a tendency to decline the longer the experiment is continued. When the yields from the first and last 6-year periods are considered there is found to be a difference of 10.6 bushels per acre in favor of the first period. These results indicate that corn following oats in untreated rotations 16 and 32 are practices not conducive to sustaining the yields of corn, and the yields from the 2-year untreated rotation with potatoes have proved to be but little better.

An improvement in yield is apparent in rotation 62, where corn is grown in a 6-year rotation with alfalfa. The yields of corn in the 6-year rotation 66, which includes one year of red clover, have about been sustained. The highest yield for any period is that recorded for rotation 37, in which sweetclover is pastured. Not only is there indicated an increase of 10.3 bushels per acre for this rotation over the annual mean of all rotations, but there is a probable error of only ±.85. The next highest yield is from rotation 62, where the difference for the same period is 4.8 bushels above the annual mean and with a probable error of ±1.92.

WHEAT

Wheat in these experiments is included in six rotations. In four wheat is planted in the spring and two include winter wheat. In outlining these experiments it was recognized that wheat was an important crop in the Belle Fourche area, particularly on the dry lands, and information was sought as to the effect on the yields of wheat of certain crop sequences under irrigated conditions over a long period. Also it is possible to observe the merits of spring planting as compared with fall planting under irrigation conditions.

Table 16 gives the yields of spring wheat. One plot is continuously cropped; there are two 2-year untreated rotations, one with sugar beets and the other oats; and the fourth includes two years of alfalfa.

Both the continuously cropped plot No. 3 and 2-year rotation 28, where spring wheat is followed by oats, have given the lowest yields. As with oats, an important factor in connection with the unsatisfactory results obtained from these methods of cropping has been weed competition. Slightly higher yields have been obtained in rotation 48, which includes two years of alfalfa immediately preceding the wheat crop, than from rotation 18, where the alterating crop is sugar beets. The differences in spring-wheat yields recorded in favor of the alfalfa rotation would not justify the practice were alfalfa grown at a loss unless compensated by an increase in the oat yields. When the oat yields from this rotation in Table 12 are referred to, it is found that for the last two periods the yields are not appreciably different from the mean for all rotations.

TABLE 16.—*Average annual yields of spring wheat compared with the annual means, showing the effect of continuous cropping, simple rotations, and alfalfa at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of spring wheat (bushels), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping:							
No. 3	Spring wheat	25.4	13.9	6.2	+1.5±1.40	−3.8±0.74	−9.0±1.03
2-year rotations:							
No. 18	Spring wheat, sugar beets	26.3	20.9	23.7	+2.4±1.23	+3.2±0.39	+8.5±0.92
No. 28	Spring wheat, oats	15.2	10.9	6.9	−8.7±1.12	−6.8±1.20	−8.3±1.14
4-year alfalfa rotation:							
No. 48	Spring wheat, oats, alfalfa (2 years)	28.5	25.2	24.0	+4.6±1.34	+7.5±0.93	+8.8±2.43

Winter wheat appears in these series of rotations in only two instances—continuously cropped plot 5 and rotation 66. Winter wheat does not fit well into the intensive cropping program that is usually required where irrigation is practiced. When it is preceded by a cultivated crop, difficulties are encountered in seeding sufficiently early in the fall to permit the development of sturdy plants that are able to survive the winter. Winterkilling has been a factor of such importance in connection with depressing yields that spring wheat is usually preferred. The results obtained from winter wheat are given in Table 17. As was the case with oats and spring wheat, the yields from the plot continuously cropped have progressively declined; the average yield for the last 6-year period was only 8.7 bushels per acre. Again weed competition has appeared to have been an important determining factor in connection with reducing the yields. Low yields for the three periods are apparent from rotation 66. In a measure this is believed to be due to the location of the tract. Even during the first few years low yields were harvested from rotation 66, as is indicated in Table 6. The lowest yield for the three periods from this rotation occurred for the second 6-year period. During this period the production for 1919 to 1921 was less than 10 bushels per acre, and in 1922 the crop was a total failure, due to winterkilling. Slightly less unfavorable conditions were encountered for the last period, 1924 to 1929.

TABLE 17.—*Average annual yields of winter wheat compared with the annual means, showing the effect of continuous cropping and a 6-year rotation with red clover included, at the Belle Fourche Field Station, 1912–1929*

Rotation	Crops in the rotation	Average annual acre yields of winter wheat (bushels), 6-year periods					
		Actual			Increase (+) or decrease (−) as compared with annual mean		
		1912–1917	1918–1923	1924–1929	1912–1917	1918–1923	1924–1929
Continuous cropping: No. 5	Winter wheat	26.8	13.3	8.7	+4.9±2.47	+1.6±1.25	−3.2±0.66
6-year rotation: No. 66	Winter wheat, red clover, sugar beets, flax, barley, corn.	16.9	10.1	15.0	−5.0±2.47	−1.6±1.25	+3.1± .65

ALFALFA

In recent years the acreage in alfalfa on the Belle Fourche project has been in excess of that devoted to any other crop. Alfalfa serves a dual purpose, in that it is the chief source of forage for livestock in the area and is extensively grown for its beneficial effect on subsequent crop yields. Farmers have long recognized that alfalfa does not respond in the varying cropping systems in a manner comparable to other crops. Even when grown continuously on the same land, yields are usually maintained for many years if the crop receives proper attention. If there is an occasional application of stable manure, even better results are obtained. It is true that alfalfa yields at times decline when grown on the same tract for long periods, but there is little evidence to indicate that this decline is due to a lowering of the productivity of the soil. Usually when yields begin to diminish, the cause may be attributed to a reduction in the stand, weed competition, or some other cause foreign to any unfavorable action alfalfa may have on the soil itself.

In outlining the various cropping systems under consideration, alfalfa was included primarily for the purpose of ascertaining its value in sustaining or improving the yields of crops with which it is associated and for measuring its value with comparable rotations receiving applications of stable manure. Therefore the yields are not summarized and compared in the same manner as has been followed in presenting the results from the other crops, but certain comparisons may be made from the results recorded in Table 9.

For the 17-year period plot 8–b, continuously cropped to alfalfa but receiving an annual application of 12 tons of stable manure since 1916, has returned 1.3 tons per acre more than plot 8–a similarly cropped but not manured. The highest annual yield also was harvested from the manured plot, which produced 6.14 tons in 1925. The rotation returning the largest annual mean for the 17 years, excluding 8–b, was that from rotation 48, the second-year crop of which produced 4.48 tons per acre, and the second highest of 4.02 tons is that from the second year of rotation 44. The mean yield from the third year of rotation 61 has been only 0.16 ton per acre more than from the third year of rotation 62, which is identical as to crops but receives no manure.

The first-year means from all rotations for the 17 years have ranged from a minimum of 1.05 tons from rotation 62 to a maximum of 2.89 tons from rotation 48. The second-year alfalfa has produced a minimum of 2.60 tons from rotation 46 to a maximum of 4.48 tons per acre from rotation 48. For the third year the range has been from a minimum of from 3.75 tons from rotation 64 to a maximum of 4.01 tons per acre from rotation 61. The largest mean yields for both the first and second years is that from rotation 48, a wheat-oats combination, including two years of alfalfa. In part this may be due to the beneficial effect these cereals may have in fitting the soil for a vigorous growth of the plants after seeding.

COMPARATIVE VALUE OF THE DIFFERENT ROTATIONS

In the preceding pages it has been shown to what extent the various crop sequences and treatments have influenced the individual crop yields, but this method of presentation does not permit one to evaluate the merits of different rotations when each is considered as a unit. It is apparent that the yields have fluctuated within wide limits as certain crop sequences have resulted in good yields, while with others less satisfactory results have been obtained. Because of the higher production costs of the staple farm crops, farmers under irrigation conditions are forced to increase their yields proportionately if they are to compete successfully with those engaged in similar enterprises on unirrigated land. While relatively large yields are essential to successful irrigated agriculture, the costs incident to obtaining such yields are of equal importance. For the last few years sugar beets have been the chief cash crop produced on the Belle Fourche project, but it does not follow that the cropping system producing the highest yields would prove to be the most profitable. Before this can be ascertained information must be available as to the net returns from the other crop or crops included in the rotation. The increase in yields in sugar beets resulting from applications of stable manure has been in excess of the yields of the same crop when alfalfa was included in the series, but yields alone furnish no evidence as to which practice would yield the largest net returns. Furthermore, farmers who believe in practicing diversification are distinctly interested in obtaining information as to which cropping system promises the largest returns after deducting production costs. For the purpose of estimating the returns a farmer might reasonably expect from the various cropping systems, Tables 18 and 19 have been prepared.

In reporting the results in this manner it is possible to measure the value of stable manure when it is applied every year to the plot continuously in alfalfa, to ascertain the value of manure in a 2-year rotation, and whether manuring is more profitable in 2-year or in 3-year rotations. In rotation 61, which receives an application of stable manure every sixth year preceding sugar beets, it is possible to determine to what extent such a practice increases the net returns by comparing it with No. 60, which does not receive such treatment. The total value of each of a number of rotations in which alfalfa is included has been determined and may be compared with others where this crop is not included. Considering the initial high first-year cost of seed and seeding together with the low yield, it is possible

to ascertain whether alfalfa should be left in for two or three years. The returns likely to result from alfalfa and corn harvested with livestock as compared with similar rotations harvested in the ordinary manner are also made available.

TABLE 18.—*Comparative value of the different rotations, Belle Fourche Field Station, 1924–1929*

Crop sequence	Rotation No.	Relative value [1]
Corn (harvested with hogs), corn (harvested with hogs,) oats, alfalfa, alfalfa (harvested with hogs)	69	$20.08
Potatoes (manure), sugar beets	21	18.09
Corn (harvested with sheep), sugar beets, oats, alfalfa, alfalfa, alfalfa (harvested with sheep)	71	16.95
Corn (harvested with hogs), flax, oats, alfalfa, alfalfa, alfalfa (harvested with hogs)	65	15.02
Oats (manure), sugar beets	23	14.92
Potatoes, sugar beets, oats (manure)	35	10.56
Potatoes, oats (manure), sugar beets	31	8.02
Oats, sugar beets	22	5.24
Alfalfa continuously (manure)	8–b	5.00
Potatoes, oats (manure), sugar beets, alfalfa, alfalfa, alfalfa	61	3.99
Potatoes, sugar beets, oats	34	2.78
Potatoes, oats, alfalfa, alfalfa	44	2.61
Alfalfa continuously	8–a	1.65
Potatoes, sugar beets, oats, alfalfa, alfalfa, alfalfa	64	1.52
Corn continuously	6	1.47
Potatoes, oats (manure)	25	1.07
Potatoes, sugar beets, alfalfa, alfalfa	40	.54
Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	60	.25
Corn, oats, sugar beets, alfalfa, alfalfa, alfalfa	62	−.97
Wheat, oats, alfalfa, alfalfa	48	−3.20
Potatoes, sugar beets	20	−3.29
Corn, oats	16	−3.54
Potatoes, corn	26	−4.20
Potatoes, oats	24	−5.16
Oats, sugar beets, alfalfa, alfalfa	42	−5.45
Sugar beets, flax, barley, winter wheat, red clover	66	−5.76
Sugar beets, oats, alfalfa, alfalfa	46	−6.01
Spring wheat, sugar beets	18	−6.29
Flax	9	−7.35
Potatoes, oats, sugar beets	30	−9.67
Corn, oats, sugar beets	32	−9.97
Oats continuously	1	−11.87
Potatoes continuously	4	−12.04
Potatoes, oats (winter rye)	27	−13.12
Winter wheat	5	−17.43
Spring wheat, oats	28	−18.86
Spring wheat continuously	3	−19.50
Sugar beets continuously	2	−21.20

[1] The minus sign (−) indicates loss.

The procedure followed in arriving at the estimated net returns for each rotation was as follows: The production costs were determined by using for cultural operations those recognized as standardized in the community, such, for instance, as contract labor and hauling sugar beets, harvesting grain, plowing, taxes, and irrigation water. Other items of expense such as disking, harrowing, and planting, were estimated, based partly upon the experience in performing these operations at the station as well as observations made among the farmers on the project. In every instance $10 per acre was allowed for repair of buildings, tool maintenance, interest, and depreciation. The cost of applying manure was estimated at $7 per acre. The unit value placed upon the different crops is believed to be not far from the average value of these crops for the last six years and is as follows: Alfalfa, $8 a ton; corn, 90 cents a bushel; potatoes, 60 cents a bushel; flax, $2.10 a bushel; wheat, $1 a bushel; barley, 72 cents a bushel;

oats, 48 cents a bushel; and sugar beets, $7 a ton. In the rotations where alfalfa, corn, or sweetclover were harvested by livestock, to the production costs were added the value of the grain or hay fed, together with the estimated costs incident to caring for the livestock. The returns were computed upon the net gains in weight or the butterfat produced and the unit value each season based upon the prevailing price being paid to farmers in the local community for such products.

The yields used in arriving at the gross returns per acre were those recorded for the last 6-year period. In compiling these net returns it is recognized that there is a wide range in the production costs on different farms, often in part due to varying local conditions as well as in efficiency in management. For comparative purposes Tables 18 and 19 may be considered accurate in that crop values are the same throughout; and while the production costs in certain instances are estimated, they are the same for all rotations.

The range in the estimated net returns per acre is from a profit of $20.08 from rotation 69 to a loss of $21.20 in continuously cropped plot 2, which is devoted to sugar beets, or an extreme difference in the net returns of $41.28 per acre. Substantial losses are recorded for all crops grown continuously on the same land with the exception of alfalfa and corn. Rotation 69, with two years of corn (both of which were pastured with hogs), oats, and three years of alfalfa (the last year pastured with hogs), returned the largest net return; and 2-year rotation 21, with potatoes (manure) and sugar beets, second. The value of harvesting corn one or more years and one crop of alfalfa with livestock in the 6-year alfalfa rotations is indicated by observing the standing of rotations 65, 69, and 71. These three cropping systems are among the first four in point of net returns. The increase in net returns is significant as a result of the application of stable manure when the results from the rotations receiving such treatment are compared with otherwise identical rotations but not so treated. In all instances $7 has been allowed for the cost of applying stable manure. An application of stable manure every six years in rotation 61 indicates a net return of $3.74 above the cost of applying; rotation 35 shows increased returns of $7.78, rotation 31 a return of $17.69, while an application every other year in rotation 21 gave returns in excess of cost of the treatment of $21.38 per acre. Even with the comparative low value placed upon alfalfa when the two continuously cropped plots are considered, it is found that a yearly application of stable manure has returned $3.35 in excess of the cost of the treatment.

The increase in the net returns from the alfalfa rotations when compared with those that do not include the crop is distinctly less than when alfalfa is pastured or manure is applied. When the average returns from 6-year rotations 60, 62, and 64 are compared with those from 30, 32, and 34, it is found that the average increase is $5.89 in favor of those including alfalfa. When the five 4-year rotations having two years of alfalfa, Nos. 40, 42, 44, 46, and 48, are compared with Nos. 20, 22 (twice), 24, and 28, there is found to be a difference in favor of the alfalfa rotations of only $1.06 per acre. This advantage of the 6-year rotations with three of alfalfa, over those where alfalfa is in for only two years, appears to be due largely

to the losses incurred from the first year of alfalfa. It has been found that the crop is invariably grown at a substantial loss the first year, while thereafter the results have shown that a slight profit over production costs is returned. Spreading these first-year losses over a 3-year instead of a 2-year period works to the advantage of the 6-year rotations.

The arrangement of the crop sequences has not only markedly influenced crop yields, but there has been found to be a wide variation in the estimated values. Rotations 30 and 34 are identical as to crops, but in one case sugar beets follows oats and in the other potatoes are the preceding crop. Rotation 34 indicates a profit of $2.78, whereas in rotation 34 there is a loss of $9.67, or a total difference of $12.45. The two alfalfa rotations with the lowest returns are 42 and 46, both of which include two years of alfalfa, oats, and sugar beets. As a rule low yields have resulted with sugar beets when grain is the preceding crop, and also for the last three years sugar-beet yields in rotation 46, where the crop immediately follows alfalfa, are among the lowest recorded, as is evident when Table 2 is consulted. As the figures in Table 18 suggest, satisfactory returns are not likely to result from such combinations.

TABLE 19.—*Rotations classified as to treatments and showing the relative values for the first 6-year period compared with those of the last 6-year period and the tendency toward gain or loss, at the Belle Fourche Field Station*

Crop sequence	Rotation No.	Relative value [1]		Difference in value [1]
		1912–1917	1924–1929	
Continuously cropped plots:				
Oats	1	−$2.24	−$11.87	−$9.63
Sugar beets	2	−17.60	−21.20	−3.60
Spring wheat	3	−3.57	−19.50	−15.93
Potatoes	4	−8.25	−12.04	−3.79
Winter wheat	5	−2.51	−17.43	−14.92
Corn	6	9.95	1.47	−8.48
Flax	9	1.56	−7.35	−8.91
Mean		−3.24	−12.56	−9.32
Untreated rotations:				
Corn, oats	16	.66	−3.54	−4.20
Spring wheat, sugar beets	18	−1.86	−6.29	−4.43
Potatoes, sugar beets	20	−4.15	−3.29	.86
Oats, sugar beets	22	1.32	5.34	4.02
Potatoes, oats	24	−9.14	−5.16	3.98
Potatoes, corn	26	−6.86	−4.20	2.66
Potatoes, oats, sugar beets	30	−10.04	−9.67	.37
Corn, oats, sugar beets	32	−4.93	−9.97	−5.05
Mean		−4.37	−4.60	−.23
Manured rotations:				
Potatoes (manure), sugar beets	21	3.49	18.09	14.60
Oats (manure), sugar beets	23	2.85	14.92	12.07
Potatoes, oats (manure)	25	−11.46	1.07	12.53
Potatoes, oats (manure), sugar beets	31	.22	8.02	7.80
Mean		−1.22	10.53	11.75
Alfalfa rotations:				
Potatoes, sugar beets, alfalfa, alfalfa	40	−9.08	.54	9.62
Oats, sugar beets, alfalfa, alfalfa	42	−7.44	−5.45	1.99
Potatoes, oats, alfalfa, alfalfa	44	−.26	2.61	2.87
Potatoes, oats, sugar beets, alfalfa, alfalfa, alfalfa	60	−4.65	.25	4.90
Corn, oats, sugar beets, alfalfa, alfalfa, alfalfa	62	−1.55	−.97	.58
Mean		−4.60	−.60	4.00

[1] The minus sign (−) indicates loss.

In Table 19 the relative value of the various rotations has been classified as to treatments, and the values for the first 6-year period are computed. This method of presentation affords an opportunity to ascertain the tendency toward gain or loss. In order that the two periods might be directly comparable, the same cost figures and crop values were used in making the computation as were adopted in arriving at the 1924 to 1929 relative values tabulated in Table 18.

When the results are grouped according to treatment it is found that the continuously cropped plots for the first 6-year period indicate a loss of $3.24, which is increased to $12.56 for the last period and a decrease in value of $9.32. The untreated rotations show a loss of $4.37 for the first period, considerably more than the average for those continuously cropped. However, when the difference in values for the two periods of these two series is compared it will be found that there is $9.09 per acre in favor of the rotation of crops. The four rotations receiving applications of stable manure return a mean loss of $1.22 for the first 6-year period but a profit of $10.53 for the second, or a total difference in favor of manuring of $11.75, even after allowing $7 per acre for the cost of application. The largest loss sustained for the first six years in these four groups is that from the alfalfa rotations and amounted to $4.60 per acre. However, for the last period the computed loss was only 60 cents per acre, or a statistical improvement in position of $4 per acre.

There has proved to be a decline in value of the continuously cropped plots in every instance. On the average the relative value of the untreated rotations has been sustained, although quite definite declines are apparent in rotations 16, 18, and 32. In two of these rotations sugar beets follow either wheat or oats and in the other a corn-wheat combination, all three of which have depressed the yields notably in certain instances. Substantial and consistent increases are apparent in all the manured rotations when the two periods are compared; the largest increase ($14.60) is attributed to rotation 21 and the least ($7.80) to a 3-year rotation 31. There are five alfalfa rotations listed in the table, and each shows a loss for the first period. Two show a loss for the last 6-year period. When the differences in value are observed in every instance there is found to be an increase in value, although small in the case of three rotations. The rotation indicating the greatest improvement is No. 40, with an increase in value of $9.62 per acre.

The effect of the inclusion of alfalfa in the several rotations has resulted in some apparent inconsistencies when yields alone are considered as well as in these tables giving the relative values. When the results from such rotations as 22 and 44 or 22 and 46 are compared it is apparent that alfalfa has not stimulated yields, and when the values are computed the net returns are less than in comparable simple rotations. On the other hand, yields have been favorably influenced and the net returns increased owing to alfalfa when rotation 20 is compared with rotation 40, and even greater differences in the net returns occur when rotation 28 is compared with rotation 48. If pasturing is practiced even more favorable returns both in yield and in the comparative net returns are evident.

From the results of these investigations it is evident that the promiscuous incorporation of alfalfa in the cropping program is no assurance that subsequent crop yields will be improved or that the

net returns will be in excess of those from comparable simple rotations. It is apparent that careful consideration must be given not only to the selection of the crop or crops to be grown but to the sequences if compensating returns are to be expected.

SUMMARY

The irrigated crop-rotation investigations herein recorded were conducted on the Belle Fourche field station of the Bureau of Plant Industry, United States Department of Agriculture, which is located on the Belle Fourche reclamation project in western South Dakota. They were begun as a part of the investigational work of the station in 1912, the year 1929 being the eighteenth season.

The soils of the project are very variable, ranging from a sandy loam to a rather heavy fine clay, the latter type predominating. Locally the heavier soils are known as gumbo. Such soils are difficult to cultivate, and the yields of certain crops often fluctuate within wide limits. Among the more important crops grown on the project and which were used in these investigations are alfalfa, sugar beets, potatoes, corn, wheat, barley, and oats. Sugar beets have been the principal cash crop.

The chief purpose of these rotations was to obtain information that would be useful to persons engaged in crop production on the project and adjoining irrigated areas having comparable soil and climatic conditions. This information was sought by comparing the yields from certain crops grown continuously on the same land with numerous crop sequences in which the rotations were otherwise untreated, ascertaining the effect of applications of stable manure in 2-year and 3-year rotations, and determining the value of alfalfa when included in certain cropping systems. The effect on crop yields of harvesting certain crops with livestock instead of in the customary manner may be observed in certain rotations; the value of rye as a green manure crop may be observed in one rotation; the effect of an application of manure in a cropping system including alfalfa may be compared with others not so treated, as well as the extent an annual application of manure to a plot continuously in alfalfa has influenced the yields of this crop.

The original series of rotations consisted of 32 different cropping systems. Later it was found desirable to increase this number by 8, making a total of 40 from which results are here reported.

To afford an opportunity of observing and comparing in a number of ways the effects of the different crop sequences and treatments to which the crops have been subjected, yields for the 18-year period are given in detail.

When the annual results of such crops as potatoes, sugar beets, oats, and wheat are observed throughout the 18 years, it is apparent that there has been wide fluctuation in the yields. In certain instances this has been a factor in minimizing the differences ordinarily to be expected between the better rotations when compared with the less desirable cropping practices, as the adverse conditions encountered have not always operated uniformly on all plots.

The annual fluctuations in the yields of oats, sugar beets, potatoes, spring wheat, and corn, expressed as a percentage of the mean yield of all plots for each crop, are presented. Potatoes have shown the greatest range, from 37 per cent in 1912 to 161 per cent in 1925. Corn has had the lowest range, from 71 per cent in 1927 to 122 per cent in 1923.

The trend of the yields of oats, sugar beets, and potatoes, expressed as a percentage of the mean annual yield of each crop, is included for the purpose of obtaining information as to the trend of the yields when untreated rotations are compared with those that have stable manure applied or where alfalfa is included. When the results are computed in this manner it is found that the mean for the untreated rotations is consistently less than the mean for all plots, that those receiving applications of stable manure are definitely higher, and that the yields from the rotations including alfalfa are but slightly more than being maintained.

The yields from the different crops are summarized and compared for the purpose of determining yield trends and to what extent production has been influenced by the different cropping systems throughout the 18 years.

The lowest yields of oats have come from the plot continuously cropped and from plots where oats followed wheat in a 2-year rotation. The next lowest yield for the last 6-year period is that from a 2-year rotation with corn as an alternating crop. Both manure and alfalfa have resulted in an increase in the yield of oats when compared with untreated rotations.

The most favorable results wlth sugar beets have been from applications of stable manure in 2-year rotations, with the pastured alfalfa rotations second and the manured 3-year rotations third. The lowest yields recorded for the last two periods are those from rotation 66, where sugar beets follow red clover. Sugar-beet yields immediately following oats, wheat, or corn have not been so satisfactory as where potatoes are the preceding crop. Even less satisfactory results occurred when alfalfa immediately preceded sugar beets.

The yields of potatoes fluctuated within wide limits. The lowest yield was from 2-year rotation 27, where oats were the alternating crop and rye was introduced for the purpose of supplying green manure. Stable manure stimulated yields, the largest yields having been harvested from rotations where manure is applied every third year. When the yields for all three periods in the alfalfa rotations are considered, yield increases are quite consistent.

Corn yields, while not high, have been relatively uniform. The plot continuously in corn has shown the greatest decline. The highest yield was that from pastured sweetclover rotation 37. Corn yields in pastured alfalfa rotations have been in excess of those from any of the others.

Yields of spring wheat have been in excess of those resulting from winter wheat. Winterkilling has been an important factor in limiting yields when fall planting is followed. Low yields have resulted when this crop is grown continuously on the same land.

Alfalfa is the nost important crop, on the basis of acreage, in the Belle Fourche area, and was included in the rotations primarily for the purpose of determing its influence in maintaining and improving the yields of associated crops. The largest acre yield was obtained from the plot continuously in alfalfa and which received an annual application of stable manure. Yields from the plots the third year from planting were in excess of those from the untreated plot continuously cropped.

The comparative net returns of the different rotations have been computed. The largest returns are from those where pasturing was practiced or manure applied. From certain cropping systems substantial losses may be expected; among them are sugar beets, oats, wheat, and potatoes grown continuously on the same land.

The relative value of the rotations, classified as to treatments and the returns from the first 6-year period compared with the last 6-year period, are given for the purpose of showing the tendency toward gain or loss. When the differences in values are considered, all continuously cropped plots have sustained losses. The values of crops from untreated plots have scarcely been maintained. The most substantial increase resulted from the applications of stable manure. The five alfalfa rotations, on the average, result in losses, but in every instance have increased in value when the last period is compared with the first.

The results here reported include information on the effect of various cropping systems on the yields of the major crops produced in the Belle Fourche area. Certain combinations have produced unsatisfactory results, whereas in others yields have been materially in excess of those ordinarily harvested, and their merits are more accurately determined by computing their comparative values than would be the case were yields only considered.

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